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TITLE: DISPLAY UNIT AND SEMICONDUCTOR LIGHT EMITTING DEVICE

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S I R:

CERTIFIED TRANSLATION

I, Masaaki Iwami of 3-22, Asagaya-minami 1-chome, Suginami-ku, Tokyo, Japan, am an experienced translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Patent Application No. 2001-062206 filed March 6, 2001.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

December 5, 2003

Date

Masaaki IWAMI

[Name of Document] Specification

[Title of the Invention] Display Unit And Semiconductor  
Light Emitting Device

[What is Claimed is]

[Claim 1] A display unit comprising:

a plurality of semiconductor light emitting devices  
arrayed on a base body;

wherein each of said plurality of semiconductor  
light emitting devices is formed by selective growth and  
has a structure that at least a periphery thereof is  
surrounded by planes grown from tilt planes tilted from a  
principal plane of said base body; and

one conductive layer is formed in self-alignment on  
the planes grown from said tilt planes.

[Claim 2] A display unit according to claim 1, wherein  
at least one of the planes grown from said tilt planes  
formed by said selective growth in each of said plurality  
of semiconductor light emitting devices includes an S-  
plane and a plane substantially equivalent thereto.

[Claim 3] A display unit according to claim 1, wherein  
said one conductive layer is formed in self-alignment in  
such a manner as to be terminated on an insulating film  
used as a mask for said selective growth.

[Claim 4] A display unit comprising:

semiconductor light emitting devices; and

a dummy device, formed together with each of said semiconductor light emitting devices, for determining an emission wavelength of said semiconductor light emitting device.

[Claim 5] A display unit according to claim 4, wherein said dummy device is disposed around each of said semiconductor light emitting devices.

[Claim 6] A display unit according to claim 4, wherein an emission wavelength of each of said semiconductor light emitting devices is changed depending on a distance between said semiconductor light emitting device and said dummy device.

[Claim 7] A display unit according to claim 4, wherein an emission wavelength of each of said semiconductor light emitting devices is changed depending on a shape of said semiconductor light emitting device.

[Claim 8] A display unit according to claim 4, wherein each of said semiconductor light emitting devices is made from a nitride based semiconductor.

[Claim 9] A display unit according to claim 4, wherein said nitride based semiconductor is a GaN based semiconductor.

[Claim 10] A display unit according to claim 4, wherein

said semiconductor light emitting devices are formed on a sapphire substrate or a silicon substrate.

[Claim 11] A display unit comprising:

at least two or more kinds of semiconductor light emitting devices different in emission wavelength, which are formed by the same crystal growth layer formed on the same base body;

wherein electrodes on said base body side are taken as a common electrode.

[Claim 12] A display unit according to claim 11, wherein said emission wavelength of one of said semiconductor light emitting devices is different from that of another of said semiconductor light emitting devices on the basis of at least one of a difference between said two semiconductor light emitting devices in positional relationship between said semiconductor light emitting device and a dummy device and a difference between said two semiconductor light emitting devices in shape of said semiconductor light emitting device.

[Claim 13] A display unit comprising:

a plurality of light emitting devices arrayed on a base body;

wherein each light permeable region is formed in a boundary region between two of said plurality of

semiconductor light emitting devices.

[Claim 14] A display unit according to claim 13, wherein two or more of said base bodies are provided, and a plurality of semiconductor light emitting devices allowing emission of light of a single color are arrayed on each of said base bodies; and

said two or more of base bodies are overlapped to each other in a light emergence direction.

[Claim 15] A display unit according to claim 13, wherein wiring portions, which are connected to said semiconductor light emitting devices on said two or more base bodies, are overlapped to each other in said light emergence direction.

[Claim 16] A display unit according to claim 13, wherein said semiconductor light emitting devices are not overlapped to each other in said light emergence direction.

[Claim 17] A semiconductor light emitting device comprising:

dummy devices having the same structure, which are formed around said semiconductor light emitting device.

[Claim 18] A semiconductor light emitting device according to claim 17, wherein an emission wavelength of said semiconductor light emitting device is changed

depending on a distance between each of said dummy devices and said semiconductor light emitting device.

[Claim 19] A semiconductor light emitting device according to claim 17, wherein an emission wavelength of said semiconductor light emitting device is changed depending on a shape of said semiconductor light emitting device.

[Claim 20] A semiconductor light emitting device according to claim 17, wherein said semiconductor light emitting device is made from a nitride based semiconductor.

[Claim 21] A semiconductor light emitting device according to claim 20, wherein said nitride based semiconductor is a GaN based semiconductor.

[Claim 22] A semiconductor light emitting device according to claim 17, wherein said semiconductor light emitting device is formed, together with said dummy devices, on a sapphire substrate or a silicon substrate.

#### [Detailed Description of the Invention]

[0001]

#### [Technical Field to which the Invention Pertains]

The present invention relates to a display unit and a semiconductor light emitting device used therefor, and

particularly to a display unit and a semiconductor light emitting device used therefor, which are fabricated by using wurtzite type compound semiconductor layers such as GaN based semiconductor layers.

[0002]

[Prior Art]

As a semiconductor light emitting device of this type, there has been known a device fabricated by forming a low temperature buffer layer overall on a sapphire substrate, forming an n-side contact layer made from Si-doped GaN thereon, and stacking, on the n-side contact layer, an n-side cladding layer made from Si-doped GaN, an active layer made from Si-doped InGaN, a p-side cladding layer made from Mg-doped AlGaN, and a p-side contact layer made from Mg-doped GaN. As commercial products of semiconductor light emitting devices having such a structure, light emitting diodes and semiconductor lasers allowing emission of light of blue and green in a wavelength range of 450 nm to 530 nm have been fabricated on a large scale.

[0003]

A sapphire substrate has been often used for growing gallium nitride thereon. In this case, however, dislocations may be emerged in crystal at a high density

because of mismatching between crystal lattices of the sapphire substrate and gallium nitride. A technique for forming a low temperature buffer layer on a substrate is one means for suppressing such defects occurring in crystal during growth thereof. In a method disclosed in Japanese Patent Laid-open No. Hei 10-312971, general crystal growth is combined with selective crystal growth in the lateral direction (ELO: Epitaxial Lateral Overgrowth) for reducing crystal defects. The method of fabricating a semiconductor light emitting device disclosed in Japanese Patent Laid-open No. Hei 10-312971 has also described that through-dislocations propagated in the direction perpendicular to a principal plane of a substrate are bent in the lateral direction by a facet structure formed in a growth region during fabrication and are thereby prevented from being further propagated, to thereby reduce crystal defects.

[0004]

A light emitting unit, used as an image display unit, can be configured such that pixels, each of which is composed of a combination of light emitting diodes or semiconductor laser devices allowing emission of light of blue, green and red, are arrayed in a matrix, wherein the pixels are independently driven. Such a light emitting



unit is also usable for a white light emitting unit or an illumination unit by allowing all of the light emitting devices to simultaneously emit light of blue, green, and red. In particular, since a light emitting device using a nitride semiconductor has a band gap energy ranging from about 1.9 eV to about 6.2 eV, a full-color display unit can be realized by using semiconductor light emitting layers made from only one kind of material. For this reason, a research on a multi-color light emitting device using a nitride semiconductor has been actively pursued.

[0005]

A technique of forming a multi-color light emitting device on the same substrate has been known, wherein a plurality of active layers having different band gap energies corresponding to different emission wavelengths are stacked, and electrodes on the substrate side are made as a common electrode and electrodes on the other side are individually provided for light of different colors. In particular, there has been known a multi-color light emitting device having a structure that respective steps, which are stepwise formed on the surface side of a substrate for extraction of electrodes, are provided for light of respective colors. However, such a multi-color light emitting device in which a plurality of pn-junction

layers are stacked has a possibility that the light emission regions in the same device act just as a thyristor. To prevent such a thyristor action, there has been disclosed a multi-color light emitting device, for example, in Japanese Patent Laid-open No. Hei 9-162444, wherein grooves are formed between one and another of stepwise light emission regions for isolating the light emission regions from each other. On the other hand, a light emitting device disclosed in Japanese Patent Laid-open No. Hei 9-92881 is configured such that an InGaN layer is formed on an alumina substrate via an AlN buffer layer, wherein a portion of the InGaN layer is doped with Al to form a blue light emission region, another portion of the InGaN layer is doped with P to form a red light emission region, and a non-doped portion of the InGaN layer is taken as a green light emission region, to thereby realize multi-color light emission.

[0006]

[Problems to be Solved by the Invention]

The above-described methods, however, have the following problems. Namely, the method using selective crystal growth in the lateral direction and the crystal growth method for forming a facet structure in a growth region in order to reduce through-dislocations propagated

from a substrate is advantageous in that the through-dislocations propagated from the substrate can be bent in the lateral direction by a facet structure portion or the line, to thereby significantly reduce crystal defects; however, these methods are disadvantageous in that, in the subsequent step, the selective crystal growth in the lateral direction is sufficiently performed or the facet structure is buried in order to form a light emission region such as an active layer, with a result that the number of processing steps is increased and a time required for fabricating the device is prolonged.

[0007]

The above-described semiconductor light emitting devices for emission of light of multi-colors have the following problems. Namely, since the processing steps become complicated, the light emitting device cannot be accurately formed, and since the crystallinity is degraded, the light emitting device with a good light emission characteristic cannot be obtained. To be more specific, in the multi-color light emitting device in which grooves are formed between one and another of the stepwise light emission regions for isolating the active layer regions from each other, anisotropic etching must be repeated by several times for isolating the active

layer regions from each other. Such repeated anisotropic etching is undesirable. This is because the crystallinity of each of the substrate and the semiconductor layer may be generally degraded by dry etching and thereby it is difficult to keep good crystallinity, and the number of steps required for mask alignment and etching is increased. In the multi-color light emitting device in which impurities are selectively doped in the single active layer formed on the substrate, since a margin must be provided for forming an opening portion in the mask layer, a sufficient distance must be set between one and another of the different light emission regions, particularly, in the case of previously estimating a fabrication error, so that it is difficult to form a micro-size light emitting device, and the number of steps is increased by selective doping.

[0008]

On the other hand, there has been known a method of fabricating a semiconductor light emitting device in a fine region by forming a layer of a nitride based semiconductor such as GaN into a pyramid shape by selective growth. In particular, a method of fabricating a light emitting device by forming a hexagonal pyramid shaped nitride based semiconductor layer by selective

growth has been disclosed, for example, in "Spatial Control of InGaN Luminescence by MOCVD Selective Epitaxy, D. Kapolnek et al., Journal of Crystal Growth, 189/190 (1998) 83-86". According to the selective growth technique described in this document, a plurality of nitride based semiconductor light emitting devices, each of which is composed of a fine hexagonal pyramid shaped GaN/InGaN layer structure, can be formed. In a process disclosed in this document, it has been described that an emission wavelength is controlled on the basis of a spacing factor. The document, however, does not describe concrete means for fabricating an image display unit configured such that devices, which allow emission of light of different colors, for example, red, green and blue, are arrayed so as to realize emission of light of multi-colors.

[0009]

An object of the present invention is to provide a display unit having a structure suitable for emission of light of multi-colors without increasing the number of fabrication steps, and a semiconductor light emitting device used therefor.

[0010]

[Means for Solving the Problems]

To achieve the above object, according to the present invention, there is provided a display unit including a plurality of semiconductor light emitting devices arrayed on a base body, wherein each of the plurality of semiconductor light emitting devices is formed by selective growth and has a structure that at least a periphery thereof is surrounded by planes grown from tilt planes tilted from a principal plane of the base body, and one conductive layer is formed in self-alignment on the planes grown from the tilt planes.

[0011]

According to the above display unit, to form a plurality of semiconductor light emitting devices on a substrate, tilt planes tilted from a principal plane of the substrate are first formed by selective growth, and then planes are grown from the tilt planes, whereby at least periphery of the device is surrounded by the planes grown from the tilt planes. Accordingly, a conductive layer is formed in self-alignment on the planes grown from the tilt planes in such a manner as to be terminated on an insulating film or the like used as a mask for selective growth. As a result, device isolation is not required or easily formed at the time of formation of electrodes, to reduce the number of steps of fabricating

the display unit.

[0012]

According to the present invention, there is provided a display unit including semiconductor light emitting devices, and a dummy device, formed together with each of the semiconductor light emitting devices, for determining an emission wavelength of the semiconductor light emitting device. The dummy device is preferably disposed around each of the semiconductor light emitting devices. The dummy devices may be formed in the same fabrication step as that for fabricating the semiconductor light emitting devices. An emission wavelength of each of the semiconductor light emitting devices is preferably changed depending on a distance between the semiconductor light emitting device and the dummy device.

[0013]

According to the present invention, there is provided a display unit including at least two or more kinds of semiconductor light emitting devices different in emission wavelength, which are formed by the same crystal growth layer formed on the same base body, wherein electrodes on the base body side are taken as a common electrode. With this configuration, since at least

two or more kinds of semiconductor light emitting devices different in emission wavelength are formed by the same crystal growth layer formed on the same base body, devices having different emission wavelengths can be formed on the same base body by the same crystal growth process. The emission wavelength of one of the semiconductor light emitting devices is preferably is different from that of another of the semiconductor light emitting devices on the basis of at least one of a difference between the two semiconductor light emitting devices in positional relationship between the semiconductor light emitting device and a dummy device and a difference between the two semiconductor light emitting devices in shape of the semiconductor light emitting device.

[0014]

According to the present invention, there is provided a display unit including a plurality of light emitting devices arrayed on a base body, wherein each light permeable region is formed in a boundary region between two of the plurality of semiconductor light emitting devices. The light permeable region allows light emitted from the back surface side to pass therethrough. With this configuration, even for a display unit



fabricated by overlapping the base bodies to each other, light emitted from the semiconductor light emitting devices formed on the base body on the back surface side can be emerged to the front surface side via the light permeable regions.

[0015]

According to the present invention, there is provided a semiconductor light emitting device including dummy devices having the same structure, which are formed around the semiconductor light emitting device. With this configuration, since the dummy devices are formed around the semiconductor light emitting device, an emission wavelength of the semiconductor light emitting device can be changed by the presence of the dummy devices without changing the structure of the semiconductor light emitting device. By using such dummy devices, a multi-color display unit including a plurality of light emitting devices having the same layer structure can be easily realized.

[0016]

[Mode for Carrying out the Invention]

A display unit of the present invention includes a plurality of semiconductor light emitting devices arrayed on a base body, characterized in that each of the

semiconductor light emitting devices is formed together with a dummy device for setting an emission wavelength of the semiconductor light emitting device, and that the semiconductor light emitting device is formed by selective growth, at least a periphery thereof is surrounded by planes grown from tilt planes tilted from a principal plane of the base body, and one conductive layer is formed in self-alignment on the planes grown from the tilt planes.

[0017]

First, each of the semiconductor light emitting devices forming the display unit of the present invention will be described. First of all, the base body used for the semiconductor light emitting device of the present invention is not particularly limited insofar as a wurtzite type compound semiconductor layer can be formed thereon. For example, as the base body, there can be used a substrate made from sapphire ( $\text{Al}_2\text{O}_3$ , whose desirable crystal plane is an A- plane, R-plane, or C-plane), SiC (having a structure of 6H, 4H or 3C), GaN, Si, ZnS, ZnO, AlN, LiMgO, LiGaO<sub>2</sub>, GaAs, MgAl<sub>2</sub>O<sub>4</sub>, or InAlGaN. Such a material for forming the base body preferably has a hexagonal or cubic system, and more preferably, has the hexagonal system. Specifically, in the case of using a

sapphire substrate, a sapphire substrate with the C-plane of sapphire taken as a principal plane thereof, which has been often used for growing a gallium nitride (GaN) based compound semiconductor thereon, is preferably used. It is to be noted that the C-plane of sapphire taken as the principal plane of the substrate used herein may include a plane tilted from the strict C-plane by an angle ranging from  $5^{\circ}$  to  $6^{\circ}$ . A silicon substrate, which has been widely used for fabricating a semiconductor device, can be also used as the base body on which a semiconductor layer having tilt planes is to be formed.

[0018]

A compound semiconductor layer is formed on the principal plane of the above-described substrate. The compound semiconductor layer is preferably made from a wurtzite type compound semiconductor in order that a facet structure will be formed thereon in the subsequent step. The compound semiconductor layer may be made from a nitride semiconductor having a wurtzite type crystal structure, a BeMgZnCdS based semiconductor, or a BeMgZnCdO based compound semiconductor. As the above nitride semiconductor having a wurtzite type crystal structure, there may be used a group III based compound semiconductor, for example, a gallium nitride (GaN) based

compound semiconductor, an aluminum nitride (AlN) based compound semiconductor, an indium nitride (InN) based compound semiconductor, an indium gallium nitride (InGaN) based compound semiconductor, or aluminum gallium nitride (AlGaN) based compound semiconductor. In particular, a gallium nitride based compound semiconductor is preferably used. In one example, an undoped GaN layer may be formed on a sapphire substrate and a Si-doped GaN layer be formed thereon. It is to be noted that, in the present invention, InGaN, AlGaN, GaN or the like does not necessarily mean a nitride semiconductor having only a strict ternary or binary mixed crystal structure. For example, InGaN can contain an impurity such as a trace of Al in a range not changing the function of InGaN without departing from the scope of the present invention. In this specification, the term "nitride" means a compound which contains one or more of B, Al, Ga, In, and Ta as the group III elements and N as the group V element, and which may contain impurities in an amount of 1% of the total amount or less, or  $1 \times 10^{20} \text{ cm}^{-3}$  or less.

[0019]

The above-described compound semiconductor layer may be grown by one of various vapor phase growth processes, for example, a metal organic chemical

deposition (MOCVD) (which is also called a metal organic vapor phase epitaxial growth (MOVPE) process), a molecular beam epitaxial growth (MBE) process, or a hydride vapor phase epitaxial growth (HVPE) process. In particular, the MOVPE process is advantageous in growing the compound semiconductor layer with good crystallinity at a high processing rate. In the MOVPE process, alkyl metal compounds are typically used as Ga, Al and In sources. Specifically, TMG (trimethyl gallium) or TEG (triethyl gallium) is used as the Ga source, TMA (trimethyl aluminum) or TEA (triethyl aluminum) is used as the Al source, and TMI (trimethyl indium) or TEI (triethyl indium) is used as the In source. Further, in the MOVPE process, a gas such as ammonia or hydrazine is used as a nitrogen source; and silane gas is used as an Si (impurity) source, germanium gas is used as a Ge (impurity) source, Cp<sub>2</sub>Mg (cyclopentadienyl magnesium) is used as a Mg (impurity) source, and a DEZ (diethyl zinc) gas is used as a Zn (impurity) source. According to the MOVPE process, for example, an InAlGa<sub>2</sub>N based compound semiconductor layer can be formed on a substrate by epitaxial growth by supplying the above gases to a front surface of the substrate heated, for example, at 600°C or more, to decompose the gases.

[0020]

According to the semiconductor light emitting device of the present invention, to form a facet structure having tilt planes tilted from the principal plane of the base body by crystal growth, a mask or a difference-in-height portion is formed on or in a surface of the above-described compound semiconductor layer as the under layer for crystal growth. The mask is a growth obstruction film formed on a buffer layer or another layer as the compound semiconductor layer formed on the base body, or may be directly on the principal plane of the base body. The mask is formed by an insulating film made from silicon oxide or silicon nitride. In the case of forming a facet structure by making use of a difference-in-height portion, crystal may be grown by making use of the difference-in-height portion in such a manner that a growth rate of a crystal plane appearing on the base body, that is, a crystal plane perpendicular to the principal plane of the base body is different from a growth rate of a crystal plane parallel to the principal plane of the base body, to form a facet structure. The difference-in-height portion can be formed, after the compound semiconductor layer is formed on the overall surface, in the compound semiconductor layer by

photolithography and anisotropic etching using a mask made from silicon oxide or silicon nitride. The shape of the mask pattern or the difference-in-height portion is not particularly limited insofar as the mask or the difference-in-height portion allows formation of a facet structure having tilt planes tilted from the principal plane of the base body. For example, the mask pattern or the difference-in-height may be formed into a shape selected from a stripe shape, a rectangular shape, a round shape, an elliptic shape, and a polygonal shape such as a triangular shape, a pentagonal shape or a hexagonal shape. The shape of the difference-in-height portion means the planar shape of the difference-in-height portion. For example, according to the present invention, the difference-in-height portion having a triangular shape means not only the difference-in-height portion projecting into a triangular pole but also the difference-in-height portion recessed into a triangular pole. A plurality of different-in-height portions may be formed overall or partially on the surface of the compound semiconductor layer. In addition, different shaped difference-in-height portions may be formed in combination.

[0021]

After formation of the mask or the different-in height portion for selective growth, a crystal growth layer including a facet structure having tilted planes is formed thereon by selective crystal growth in accordance with the same manner as that for forming the above-described compound semiconductor layer, for example, one of various vapor phase growth processes, such as the metal organic chemical deposition (MOCVD) (which is also called the metal organic vapor phase epitaxial growth (MOVPE) process), the molecular beam epitaxial growth (MBE) process, or the hydride vapor phase epitaxial growth (HVPE) process.

[0022]

According to the semiconductor light emitting device of the present invention, in the case of forming a crystal growth layer having a facet structure by crystal growth, each of the tilted planes tilted from the principal plane of the base body is preferably selected from an S-plane and a plane substantially equivalent thereto, and a {11-22} plane and a plane substantially equivalent thereto. Here, the plane substantially equivalent to the S-plane means a plane tilted from the S-plane at an angle ranging from  $5^{\circ}$  to  $6^{\circ}$ . For example, if the C-plane is selected as the principal plane of the



base body, the S-planes or the planes substantially equivalent thereto can be easily formed. The S-plane is a stable plane which is relatively easily, selectively grown on the (C+)-plane. It is to be noted that the S-plane is expressed by a (1-101) plane in Millar indices for the hexagonal system. The (C+)-plane and (C-)-plane are present as the C-plane, and similarly, the (S+)-plane and (S-)-plane are present as the S-plane. According to the present invention, unless otherwise specified, the (S+)-plane, which is grown on the (C+)-plane of the GaN layer, is taken as the S-plane. The (S+)-plane is stable more than the (S-)-plane. In addition, the (C+)-plane is expressed by a (0001) plane in Millar indices.

[0023]

In the case of forming a crystal layer by growing a gallium nitride based compound semiconductor on the S-plane, the number of bonds of gallium (Ga), which bonds are to be bonded to nitrogen (N), on the S-plane is two or three. The number of Ga to N on the S-plane is smaller than the number of bonds of Ga to N on the (C-)-plane but is larger than the number of Ga to N on any other crystal plane. Here, since the (C-)-plane cannot be actually formed on the (C+)-plane, the number of bonds of Ga to N on the S-plane is largest. For example, in the case of

growing a wurtzite type nitride on a sapphire substrate with the (C+)-plane taken as the principal plane, a surface of the nitride generally becomes the (C+)-plane; however, the S-plane of the nitride can be stably formed by making use of selective growth. Nitrogen (N) is liable to be desorbed on a plane parallel to the (C+)-plane, and therefore, N is bonded to Ga by means of only one bond of Ga. On the other hand, on the tilted S-plane, N is bonded to Ga by means of at least one or more bonds of Ga. As a result, a V/III ratio of the stacked structure selectively grown on the S-plane is effectively increased, to improve the crystallinity of the stacked structure selectively grown on the S-plane. Further, in the case of growing a crystal growth layer along the direction different from the orientation of the principal plane of a substrate, since dislocations propagated upwardly from the substrate are bent, it is possible to reduce occurrence of crystal defects.

[0024]

The kind of tilt planes of a facet structure formed on the crystal growth layer is controlled by a growth condition at the time of crystal growth, and a shape of a difference-in-height portion. For example, in the case where a difference-in-height portion extending in a

stripe shape is formed in a surface of a gallium nitride based semiconductor layer, if the longitudinal direction of the stripe is a  $\langle 11-20 \rangle$  direction, a facet structure having the S-planes as tilt planes is formed. In this case, the facet structure has an inverse V-shape in cross-section as viewed in the direction perpendicular to the longitudinal direction of the stripe. Since the shape of the difference-in-height portion is not limited to the stripe shape, the cross-section of the crystal growth layer can have any other shape than the stripe shape, for example, a rectangular shape, a round shape, a triangular shape, or a hexagonal shape. The crystal growth layer is grown depending on the shape of the difference-in-height portion. If the extending direction of an end portion of the difference-in-height portion is set to be approximately perpendicular to a  $\langle 1-100 \rangle$  direction or the  $\langle 11-20 \rangle$  direction, then a difference in growth rate between growth in the lateral direction and growth in the vertical direction appears, to obtain a facet structure.

[0025]

A first conductive type cladding layer, an active layer, and a second conductive type cladding layer are stacked on the crystal growth layer having the facet structure in such a manner as to be located in a region

extending in parallel to the tilt planes of the facet structure. As a result of observing a facet structure grown on a crystal growth layer by using cathode luminescence in an experiment performed by the present inventors, it was revealed that the S-plane as the tilt plane of the facet structure has good crystallinity and exhibits a higher luminous efficiency as compared with the (C+)-plane. In particular, a growth temperature for growing an InGaN active layer is set in a range of 700 to 800°C. At this temperature, a decomposition efficiency of ammonia is low, and thereby a large amount of an N source is required. As a result of observation of the surface of the tilt plane by AFM, it was found that the tilt plane has regular crystal steps and is thereby suitable for incorporation of InGaN. Furthermore, the state of a growth surface of a Mg-doped layer at the AFM level is generally poor; however, it was found that the growth of the S-plane allows the Mg-doped layer to be grown in a good surface state and makes a doping condition for the Mg-doped layer very different from a doping condition for the Mg-doped layer on the (C+)-plane. As a result of microscopic photoluminescence mapping, although the surface of the layer doped with Mg formed on the (C+)-plane by the usual manner has an unevenness of a pitch of

about 1  $\mu\text{m}$ ; however, the surface of the Mg-doped layer formed on the S-plane obtained by selective growth was even and measured at a resolution of about 0.5 to 1  $\mu\text{m}$ . Further, as a result of observation by SEM, it was revealed that the flatness of the tilted plane, that is, the S-plane is superior to that of the (C+)-plane.

[0026]

With respect to the first conductive type cladding layer, the active layer, and the second conductive type cladding layer, which are stacked in the region extending in parallel to the tilt planes, the conductive type of the first conductive type cladding layer is a p-type or an n-type, and the conductive type of the second conductive type cladding layer is the n-type or the p-type. For example, in the case where a crystal growth layer having the S-planes is made from a silicon-doped gallium nitride based compound semiconductor, an n-type cladding layer may be made from the same silicon-doped gallium nitride based compound semiconductor, an InGaN layer be formed as an active layer thereon, and a magnesium-doped gallium nitride based compound semiconductor layer be formed as a p-type cladding layer thereon, to thus form a double hetero structure. The active layer may have a structure in which an InGaN layer

is held between AlGa<sub>N</sub> layers or an AlGa<sub>N</sub> layer is provided on one side of the InGa<sub>N</sub> layer. The active layer may be a single bulk active layer; however, it may be of a quantum well structure such as a single quantum well (SQW) structure, a double quantum well (DQW) structure, or a multi-quantum well (MQW) structure. In the case of adopting the quantum well structure, one or more barrier layers are used for separating quantum wells from each other. The use of the InGa<sub>N</sub> layer as the active layer is advantageous in facilitating the fabricating process and enhancing a light emission characteristic of the device. Another advantage of the use of the InGa<sub>N</sub> layer is that the InGa<sub>N</sub> layer can be particularly, easily crystallized with good crystallinity on the S-plane having the structure from which nitrogen atoms are less adsorbed, with a result that the luminous efficiency can be enhanced. In addition, even in a state that a nitride semiconductor is not doped with an impurity, the conductive type of the nitride semiconductor becomes the n-type because of holes of nitrogen generated in crystal; however, the nitride semiconductor is generally doped with a doner impurity such as Si, Ge, or Se during crystal growth, to obtain an n-type nitride semiconductor having a desirable carrier concentration. On the other

hand, a p-type nitride semiconductor is obtained by doping an acceptor impurity such as Mg, Zn, C, Be, Ca, or Ba in crystal. In this case, to obtain a p-type nitride semiconductor having a high carrier concentration, the nitride semiconductor having been doped with an acceptor impurity may be annealed in an inert gas atmosphere such as nitrogen or argon at a temperature of 400°C or more, or activated by irradiation of electron beams, microwaves, or light.

[0027]

These first conductive type cladding layer, the active layer, and the second conductive type cladding layer extend within planes parallel to tilt planes. The formation of these layers within the planes parallel to the tilt planes can be easily performed by continuing the crystal growth after formation of a crystal layer having the tilt planes. The first conductive type cladding layer can be made from the same material having the same conductive type as that of a crystal layer having the S-planes. In this case, after formation of the crystal layer having the S-planes, the first conductive cladding layer may be formed by depositing the same material while continuously adjusting a concentration of source gases for depositing the material. Alternatively, the first

conductive cladding layer may be configured as part of the crystal layer having the S-planes.

[0028]

Electrodes are directly or indirectly connected to the first and second conductive type cladding layers with the active layer put therebetween. Each electrode is formed for each device; however, one of a p-type electrode and an n-type electrode is made common to a plurality of devices. To reduce a contact resistance, a specific contact layer may be formed and then an electrode be formed on the contact layer. In general, respective electrodes are obtained by forming a multi-layer metal film by vapor-deposition, and then finely dividing the multi-layer metal film into electrode parts belonging to respective device regions by photolithography and lift-off. Each electrode can be formed on one side of a selective crystal growth layer or a substrate, or may be on each of both sides of a selective crystal growth layer or a substrate in order to realize higher density wiring of the electrodes. In addition, electrodes independently driven can be obtained by a manner of forming the same material film and finely patterning the film into electrode parts, or may be obtained by a manner of forming different electrode parts



made from different materials in respective device regions.

[0029]

According to the semiconductor light emitting device of the present invention, a luminous efficiency can be enhanced by making use of desirable crystallinity of tilt planes (S-planes) formed by selective growth. In particular, in the case of injecting a current only in the S-plane with good crystallinity formed by a layer of a group III nitride based semiconductor, since the S-plane is excellent in incorporation of In and has good crystallinity, it is possible to enhance the luminous efficiency. To fabricate a multi-color light emitting device by using an InGaN layer as an active layer, indium (In) is required to be sufficiently incorporated as crystal. From this viewpoint, by forming the above InGaN active layer on the S-plane, the luminous efficiency of the device can be enhanced by making use of good crystallinity of the S-plane. The structure that the InGaN active layer is formed on the S-plane is also advantageous for emission of light of multi-colors. To be more specific, in the case of crystal growth on the (C+)-plane, gallium has only one bond, which is bonded to nitrogen liable to be desorbed, with a result that it is

impossible to increase an effective V/III ratio by crystal growth of InGaN performed by using ammonia whose decomposition efficiency is low. Accordingly, many measures are required to form the InGaN layer with good crystallinity by crystal growth. Meanwhile, in the case of crystal growth on the S-plane, since the number of bonds of gallium to nitrogen on the S-plane is as large as two or three, the desorption of nitrogen becomes small and thereby the effective V/III ratio becomes high. In general, the quality of crystal grown on not only the S-plane but also any other plane than the (C+)-plane becomes high because the number of bonds of gallium to nitrogen tends to be increased for growth on any other crystal growth than the (C+)-plane. The growth of crystal on the S-plane is thus advantageous in that the amount of In incorporated in the crystal grown on the S-plane becomes high. The increased amount of In incorporated in crystal grown on the S-plane is effective for fabricating a multi-color light emitting device because a band gap energy is determined on the basis of the amount of In incorporated in crystal.

[0030]

In one example of the semiconductor light emitting device of the present invention, at least a periphery of

the device is surrounded by tilt planes of a facet structure formed by selective growth, and one conductive layer is formed in self-alignment on planes grown from the tilt planes. Since the periphery of the device is surrounded by the tilt planes of the facet structure, the conductive layer is formed while being tiled with respect to the principal plane of the base body, and an end portion of the conductive layer is terminated on a mask or a difference-in-height portion used for selective growth. Accordingly, the conductive layer in each device region is formed in self-alignment only on the tilt plane portions. For example, for a device structure that a first conductive type cladding layer, an active layer, and a second conductive type cladding layer are formed in this order from the base body side, the second conductive type cladding layer is equivalent to the one conductive layer formed in self-alignment. The one conductive layer is, therefore, is not required to be divided into parts belonging to respective device regions by etching. As a result, the light emitting devices can be arrayed at a high density.

[0031]

According to the semiconductor light emitting device of the present invention, as will be described

later, an emission wavelength of the semiconductor light emitting device can be controlled by disposing a specific dummy device. On the other hand, the emission wavelength of the semiconductor light emitting device can be controlled by changing at least one of a composition and a thickness of an active layer forming a light emission region of the semiconductor light emitting device. Only the composition or the thickness of the active layer may be changed, or both the composition and the thickness of active layer may be changed. The change in composition and/or thickness of an active layer can be used in combination of provision of a dummy device (which will be described later) or may be caused by the provision of a dummy device. The composition of an active layer of a semiconductor light emitting device can be adjusted by changing a mixing ratio of elements of a ternary or binary mixed crystal constituting the active layer. In the case of using an InGa<sub>N</sub> layer as the active layer, a semiconductor light emitting device for emitting light of a long-wavelength can be obtained by increasing the amount of In contained in the active layer. In crystal growth of an InGa<sub>N</sub> layer, a migration length of InGa<sub>N</sub>, particularly, indium (In) is estimated as about 1 to 2  $\mu\text{m}$  at about 700°C optimum for crystal growth of the InGa<sub>N</sub>

layer having a relatively large amount of In. This is because InGaN precipitated on a mask is grown from a selective growth portion only by about 1 to 2  $\mu\text{m}$ . The migration length of In may be thus regarded as about 1 to 2  $\mu\text{m}$ . Since the migration length of In in InGaN in a region from the mask portion to the growth portion is relatively short, that is, about 1 to 2  $\mu\text{m}$ , the content of In or the thickness of InGaN may differ in such a region.

[0032]

In one example of the semiconductor light emitting device of the present invention, as will be described later, an emission wavelength of the semiconductor light emitting device can be controlled by changing a layout of dummy device. On the other hand, an emission wavelength of the semiconductor light emitting device can be also controlled by changing a shape of the light emitting device. The change of the shape of the light emitting device can be realized by changing a shape of an opening portion formed in a mask for selective growth. For example, a semiconductor light emitting device having a first emission wavelength may be formed by selective growth from a circular or regular hexagonal shaped opening portion, and a semiconductor light emitting

device having a second emission wavelength different from the first emission wavelength be formed by selective growth from a band or stripe shaped opening portion. The change of the opening portion formed in a mask for selective growth can be used in combination of a dummy device (which will be described later). In the case of forming a facet structure having tilt planes (S-planes) by selective growth from a stripe-shaped opening portion formed in a mask, a light emission region formed on the tilt planes is taken as a long-wavelength region, and a light emission region formed on the C-plane is taken as a short-wavelength region. This may be reversed depending on a growth condition.

[0033]

In particular, according to one example of the semiconductor light emitting device of the present invention, the semiconductor light emitting device can be formed together with a dummy device. The dummy device is formed on the same base body as that on which the semiconductor light emitting device is formed, by the same fabrication method as that for fabricating the semiconductor light emitting device. The dummy device is disposed around the semiconductor light emitting device for setting a spacing factor of the semiconductor light

emitting device. As described above, in the case of fabricating a semiconductor light emitting device by forming a hexagonal pyramid shaped nitride based semiconductor layer by selective growth, as described in "Spatial Control of InGaN Luminescence by MOCVD Selective Epitaxy", D. Kapolnek et al., Journal of Crystal Growth, 189/190 (1998) 83-86", an emission wavelength of the semiconductor light emitting device can be controlled on the basis of the spacing factor thereof. Accordingly, the emission wavelength of the semiconductor light emitting device can be positively controlled by disposing a dummy device.

[0034]

The dummy device will be more fully described below. Various layouts of dummy devices can be adopted. For example, a plurality of pyramid shaped dummy devices may be arrayed around a semiconductor light emitting device for emission of light in such a manner as to be spaced at equal intervals, or to be continuous to each other in a closed loop shape. Various shapes of dummy devices can be adopted. For example, a long-sized rectangular or circular-arc shaped dummy device may be combined with a hexagonal pyramid shaped dummy device, or dummy devices may be concentrically arranged. The layout and shape of

dummy devices formed together with a semiconductor light emitting device are not limited to those described above but may be freely set insofar as the dummy devices can control the spacing factor of the semiconductor light emitting device. In general, only one semiconductor light emitting device is disposed adjacently to dummy devices; however, a plurality of semiconductor light emitting devices may be disposed adjacently to the dummy devices. A layer structure of a dummy device is not necessarily required to strictly correspond to that of a semiconductor light emitting device for emission of light. A dummy device may be identical to or different from a semiconductor light emitting device in terms of thickness of each layer, constituent material, and impurity concentration. A layer or an impurity may be added only to a dummy device. A stacked layer of a dummy device having a height different from that of a stacked layer of a semiconductor light emitting device may be formed by forming a difference-in-height portion only for the dummy device in order to control the spacing factor of the semiconductor light emitting device. If the layer structure of a dummy device is the same as that of a semiconductor light emitting device for emission of light, then there can be obtained an advantage of fabricating



the dummy device and the semiconductor light emitting device by the same fabrication process. A distance between a dummy device and a semiconductor light emitting device for emission of light is one spacing factor, and an emission wavelength of the semiconductor light emitting device can be controlled by adjusting the distance. In addition, the shape of a semiconductor light emitting device is used, as described above, for controlling an emission wavelength of the semiconductor light emitting device.

[0035]

Formation of a semiconductor light emitting device for emission of light of red, a semiconductor light emitting device for emission of light of blue, and a semiconductor light emitting device for emission of light of green by controlling a layout of a dummy device formed together with each of the semiconductor light emitting devices will be described below. For example, if a dummy device is disposed on a loop which has a larger size (for example, 40  $\mu\text{m}$ ) and is located around a semiconductor light emitting device, the semiconductor light emitting device allows emission of light of red; if a dummy device is disposed on a loop which has a smaller size (for example, 20  $\mu\text{m}$ ) and is located around a semiconductor

light emitting device, the semiconductor light emitting device allows emission of light of green; and if a dummy device is disposed on a loop which has a larger size and is located around an elongated rectangular shaped semiconductor light emitting device, the semiconductor light emitting device allows emission of light of blue.

[0036]

A display unit of the present invention will be described below. The display unit of the present invention has a structure including an array of a plurality of semiconductor light emitting devices. In particular, the display unit of the present invention can be configured as a multi-color display unit by arraying semiconductor light emitting devices having different emission wavelengths on the same substrate (or base body), or arraying semiconductor light emitting devices of each of different emission wavelengths on one of separate substrates (or base bodies) and stacking the substrates (or base bodies) to each other. In the case of stacking the substrates each other, each region between two of a plurality of semiconductor light emitting devices may have a light permeable region having a size of at least 1  $\mu\text{m}$  or more. If the size of the light permeable region is less than 1  $\mu\text{m}$ , light emitted from each semiconductor

light emitting device formed on the back side substrate may be reflected from a region other than the light permeable region of the front side substrate by the effect of a distance between the substrates stacked to each other and extension of a beam, to thereby degrade the lighting intensity.

[0037]

For example, according to the present invention, in the case of forming a full-color image display unit by arraying semiconductor light emitting devices allowing emission of light of red, blue and green, a substrate on which only the devices allowing emission of light of red have been arrayed, a substrate on which only the devices allowing emission of light of blue have been arrayed, and a substrate on which only the devices allowing emission of light of green have been arrayed are stacked to each other in the light emergence direction, wherein light emitted from each of the light emitting devices arrayed on the substrate located on the back side in the light emergence direction is allowed to pass through a light permeable region formed on the substrate located on the front side. At this time, the semiconductor light emitting devices are preferably not overlapped to each other in the light emergence direction, but wiring

portions for supplying a power or a signal to the semiconductor devices may be overlapped to each other in the light emergence direction. If the semiconductor light emitting devices are overlapped to each other in the light emergence direction, colors of light emitted from the semiconductor light emitting devices may be mixed with each other, failing to obtain a desired image, and accordingly, it may be desired that the semiconductor light emitting devices be not overlapped to each other in the light emergence direction. In the case of using a metal thin film as a wiring material for lowering the resistance of a wiring portion, the wiring portion may cut off transmission of light therethrough; however, according to the present invention, since the wiring portions for supplying powers or signals to the semiconductor light emitting devices, which are regions cutting off transmission of light, are overlapped to each other in the light emergence direction, it is possible to make use of light permeable regions other than the overlapped wiring portions and hence to keep a good light permeability, and also to improve the degree of freedom of layout of the devices.

[0038]

In the case of growing semiconductor light emitting

devices on a sapphire substrate, such light permeable region may be obtained by transferring the devices onto a light permeable substrate such as a glass substrate or a plastic substrate; thinly polishing or grinding a sapphire substrate or another crystal growth substrate such as a silicon substrate for improving the light permeability of the substrate; or forming an opening portion or a thinned portion for light transmission by etching. A lens or another optical member can be interposed between substrates, the lens or another optical member may serve as a spacer between the substrates. In the case of transferring light emitting devices to a substrate such as a glass substrate or a plastic substrate, or thinly polishing or grinding a sapphire substrate or another substrate, a rigidity of the substrate tends to be lost; however, a flexibility of the substrate is rather improved, to easily solve a problem associated with cracking or camber of the substrate caused during heat-treatment thereof.

[0039]

The display unit of the present invention can be used as a white light or mixed-color light illumination unit by arraying a plurality of semiconductor light emitting devices allowing emission of light of three

primary colors or two or more colors and injecting the same current in each of light emission regions of the devices. The display unit of the present invention is not limited to that including light emitting devices allowing emission of light of red, blue, and green, but may be configured as that including light emitting devices allowing emission of light of two colors or four or more colors.

[0040]

The display unit of the present invention can be driven by the same point-sequence or line-sequence manner as that used for driving an active matrix type liquid crystal display unit. Semiconductor light emitting devices having different emission wavelengths may be of different device structures. For example, as a blue or green light emitting diode, a gallium nitride based double-hetero structure multi-layer crystal grown on a sapphire substrate can be used, and as a red light emitting diode, an aluminum gallium arsenide or indium aluminum gallium phosphide based double-hetero structure multi-layer crystal grown on a gallium arsenide substrate can be used. Three light emitting diodes having different emission wavelengths constitute each of pixels, and in this case, the different emission wavelengths are not

limited to those for emission of light of red, blue and green but may be those for emission of light of other colors. The semiconductor light emitting device of the present invention is not limited to a light emitting diode but may be a semiconductor laser device having a specific resonator.

[0041]

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the drawings. It is to be noted that the present invention is not limited to the following embodiments and may be modified and changed without departing from the scope of the present invention.

[0042]

[First Embodiment]

A display unit according to this embodiment will be described with reference to FIGS. 1 to 4. The display unit in this embodiment includes a display portion having a structure that pixels, each of which is composed of three semiconductor light emitting devices allowing emission of light of red, blue and green, are arrayed in the vertical and horizontal directions, that is, in a matrix.

[0043]

FIG. 1 is a plan view showing a configuration of a one pixel portion of the display unit according to this embodiment. Referring to FIG. 1, a red light emitting diode 11R, a blue light emitting diode 11B, and a green light emitting diode 11G are arrayed in such a manner as to be obliquely offset from each other in each of the vertical direction (V-direction in FIG. 1) and the horizontal direction (H-direction in FIG. 1). Each of the light emitting diodes 11R, 11B and 11G is fabricated by forming a first conductive type cladding layer, an active layer, and a second conductive type cladding layer on a GaN based nitride semiconductor layer. These devices are formed on the same sapphire substrate 10 by the same processing steps. Each of the light emitting diodes 11R, 11B and 11G is formed into an approximately hexagonal pyramid shape. It is to be noted that light emitted from each of these devices is emerged in the direction from a front surface to a rear surface of the figure.

[0044]

Six dummy devices 12R are formed at points which are separated radially from the red light emitting diode 11R in six directions, and more specifically, formed at corners of a hexagonal shape centered at the red light emitting diode 11R. In other words, the red light



emitting diode 11R is positioned at the center of the hexagonal shape having the six corners at which the dummy devices 12R are located. A magnesium-doped GaN layer of the red light emitting diode 11R is connected to an approximately rectangular p-side electrode 15. The p-side electrode 15 is integrated with or electrically connected to a thin, stripe shaped wiring layer 18 extending in the horizontal direction. Similarly, six dummy devices 13B are formed at points which are separated radially from the blue light emitting diode 11B in six directions, and more specifically, formed at corners of a flattened hexagonal shape (one pair of opposed sides longer than another pair of opposed sides) centered at the blue light emitting diode 11B. In other words, the blue light emitting diode 11B is positioned at the center of the flattened hexagonal shape having the six corners at which the dummy devices 13B are located. Unlike the red light emitting diode 11R and the green light emitting diode 11G, the blue light emitting diode 11B is formed into a stripe shape. A magnesium-doped GaN layer of the blue light emitting diode 11B is connected to an approximately rectangular p-side electrode 16. The p-side electrode 16 is integrated with or electrically connected to a thin, stripe shaped wiring layer 19 extending in the horizontal

direction. Similarly, six dummy devices 14G are formed at points which are separated radially from the green light emitting diode 11G in six directions, and more specifically, formed at corners of a hexagonal shape centered at the green light emitting diode 11G. In other words, the green light emitting diode 11G is positioned at the center of the hexagonal shape having the six corners at which the dummy devices 14G are located. A magnesium-doped GaN layer of the green light emitting diode 11G is connected to an approximately rectangular p-side electrode 17. The p-side electrode 17 is integrated with or electrically connected to a thin, stripe shaped wiring layer 20 extending in the horizontal direction.

[0045]

The dummy devices 12R, 13B and 14G will be described in detail below. The dummy devices 12R (13B or 14G) are disposed around the light emitting diode 11R (11B or 11G) for setting a spacing factor of the light emitting diode 11R (11B or 11G). Since a wavelength of light emitted from the light emitting diode 11R (11B or 11G) is controlled by adjusting the spacing factor of the light emitting diode 11R (11B or 11G), the wavelength of light emitted from the light emitting diode 11R (11B or 11G) can be positively controlled by disposing the dummy

devices 12R (13B or 14G) around the light emitting diode 11R (11B or 11G). FIG. 2 shows a selective growth mask used for each of the red, blue and green light emitting diodes, and a pattern of each of the red, blue and green light emitting diodes and dummy devices formed by selective growth. In this figure, each selective growth mask is shown on the upper side, and the pattern of each of the light emitting diodes and the dummy devices is shown on the lower side.

[0046]

Referring to FIG. 2, a mask for red shown on the left side designated by character (R) has, at its center, an opening portion 25R for selective growth of the red light emitting diode 11R and also has, at corners of a hexagonal shape centered at the opening portion 25R, six opening portions 26R for selective growth of the dummy devices 12R. A size of each of the opening portions 25R and 26R may be set in a range of about 0.1  $\mu\text{m}$  to 10  $\mu\text{m}$ , and be formed into a polygonal shape such as an approximately hexagonal shape, a circular shape, or an elliptic shape. A distance between each of the opening portions 26R for forming the dummy devices 12R and the opening portion 25R for forming the red light emitting diode 11R may be typically set to about 20  $\mu\text{m}$ . As a

result, a size of the hexagonal shape formed by the six opening portions 26R becomes about 40  $\mu\text{m}$ . By using such a mask for red, the hexagonal shaped red light emitting diode 11R and the dummy devices 12R are formed by selective growth from the opening portions 25R and 26R of the mask for red, respectively.

[0047]

Referring to FIG. 2, a mask for blue shown at the central portion designated by character (B) has, at its center, an approximately rectangular shaped opening portion 25B for selective growth of the blue light emitting diode 11B and also has, at corners of a flattened hexagonal shape centered at the opening portion 25B, six opening portions 27B for selective growth of the dummy devices 13B. Like the size of each of the opening portions 26R and the opening portion 25R, a size of each of the opening portions 27B may be set in a range of about 0.1  $\mu\text{m}$  to 10  $\mu\text{m}$ . A size of the approximately rectangular shaped opening portion 25B may be typically set to a value being about two to ten times the size of the opening portion 25R. A distance between each of the opening portions 27B for forming the dummy devices 13B and the opening portion 25B for forming the blue light emitting diode 11B may be set as follows: namely, a

distance between each of the opening portions 27B and an end portion, closer to the opening portion 27B, of the rectangular shaped opening portion 25B may be set to about 20  $\mu\text{m}$ . As a result, a longitudinal size of the flattened hexagonal shape formed by the six opening portions 27B becomes a value obtained by adding the longitudinal size of the opening portion 25B to about 40  $\mu\text{m}$ . By using such a mask for blue, the hexagonal shaped blue light emitting diode 11B and the dummy devices 13B are formed by selective growth from the opening portions 25B and 27B of the mask for blue, respectively.

[0048]

Referring to FIG. 2, a mask for green shown on the right side designated by character (G) has, at its center, an opening portion 25G for selective growth of the green light emitting diode 11G and also has, at corners of a hexagonal shape centered at the opening portion 25G, six opening portions 28G for selective growth of the dummy devices 14G. A size of each of the opening portions 25G and 28G may be set in a range of about 0.1  $\mu\text{m}$  to 10  $\mu\text{m}$ , and be formed into a polygonal shape such as an approximately hexagonal shape, a circular shape, or an elliptic shape. A distance between each of the opening portions 28G for forming the dummy devices 14G and the

opening portion 25G for forming the green light emitting diode 11G may be typically set to about 10  $\mu\text{m}$ . As a result, a size of the hexagonal shape formed by the six opening portions 28G becomes about 20  $\mu\text{m}$ . By using such a mask for green, the hexagonal shaped green light emitting diode 11G and the dummy devices 14G are formed by selective growth from the opening portions 25G and 28G of the mask for green, respectively.

[0049]

Since the spacing factors of the light emitting diodes 11R, 11B and 11G are set to be different from each other by providing the dummy devices 12R, 13B and 14G, which are different from each other in terms of size, shape and/or location, around the light emitting diodes 11R, 11B and 11G respectively, emission wavelengths of the light emitting diodes 11R, 11B and 11G are different from each other. The red light emitting diode 11R typically has an energy gap of about 2.2 eV and emits light having a wavelength of about 620 nm. The blue light emitting diode 11B typically has an energy gap of about 2.7 eV and emits light having a wavelength of about 470 nm. The green light emitting diode 11G typically has an energy gap of about 2.5 eV and emits light having a wavelength of about 520 nm. According to this embodiment,

the light emitting diodes 11R, 11B and 11G are formed on the same sapphire substrate 10 in such a manner that the light emitting diodes 11R, 11B and 11G have the same layer structure, and the dummy devices 12R, 13B and 14G are disposed around the light emitting diodes 11R, 11B and 11G, respectively, so as to make the emission wavelengths of the light emitting diodes 11R, 11B and 11G different from each other. The present invention, however, is not limited thereto but may be configured such that one or two of light emitting diodes for red, blue and green have different layer structures, and dummy devices be provided around the remaining one or two light emitting diodes, respectively.

[0050]

A structure of each of the light emitting diodes for red, blue and green and a structure of a wiring portion associated therewith will be described with reference to FIGS. 3 and 4. FIG. 3 is a sectional view taken on line III-III of FIG. 1, showing a sectional structure of the red light emitting diode 11R. The red light emitting diode 11R, the blue light emitting diode 11B and the green light emitting diode 11G have the same layer structure except for portions subjected to control of emission wavelengths by the dummy devices 12R, 13B and

14G (for example, impurity concentrations, crystal structures, and the like). Referring to FIG. 3, the red light emitting diode 11R is configured as a GaN based light emitting diode. The red light emitting diode 11R is fabricated such that an under growth layer 32 typically composed of an AlN buffer layer and a silicon-doped GaN semiconductor layer is formed on the sapphire substrate 10 with the (C+)-plane of sapphire taken as a principal plane thereof, and a hexagonal pyramid shaped GaN layer 35 is formed thereon by selective growth. To be more specific, a selection mask 33 composed of a silicon oxide film is formed on the under growth layer 32, an opening portion 34 is formed in the selection mask 33, and the hexagonal pyramid shaped GaN layer 35 is formed by selective growth from the opening portion 34. The opening portion 34 is equivalent to the opening portion 25R formed in the mask shown in FIG. 2. The hexagonal pyramid shaped GaN layer 35 is formed by selective growth from the opening portion 34 formed in the selection mask 33 by the MOCVD process or the like.

[0051]

In the case of growing the GaN layer 35 on the sapphire substrate 10 with the C-plane of sapphire taken as the principal plane thereof, the GaN layer 35 is



formed into the hexagonal pyramid shape covered with (1-101) planes called the S-planes. The conductive type of the GaN layer 35 is taken as an n-type by doping silicon into the GaN layer 35. The GaN layer 35 is grown from the opening portion 34 formed in the selection mask 33, and one conductive layer will be formed in self-alignment on planes grown from the S-planes as the tilt planes of the GaN layer 35. It is to be noted that the GaN layer 35 is grown in self-alignment in such a manner as to be terminated on the selection mask 33 composed of the insulating film used for selective growth.

[0052]

The tilt plane portions, that is, the S-plane portions of the GaN layer 35 function as a cladding layer constituting part of a double-hetero structure. An InGaN layer 36 as an active layer is formed to cover the GaN layer 35, and a magnesium-doped GaN layer 37 is formed on the InGaN layer 36. The magnesium-doped GaN layer 37 also functions as a cladding layer constituting part of the double-hetero structure. The magnesium-doped GaN layer 37 is grown in self-alignment, that is, extends along the tilt planes (S-planes) toward the selection mask 33 formed of the insulating film and is terminated on the selection mask 33. The terminated point of the magnesium-

doped GaN layer 37 corresponds to the peripheral end portion of the light emitting device. Accordingly, in the case of fabricating the display unit, the GaN layer 35 as the cladding layer, the InGaN layer 36 as the active layer, and the magnesium-doped GaN layer 37 as the cladding layer are not required to be subjected to device isolation. In other words, each of the light emitting devices for forming the display unit can be arrayed in self-alignment at the position corresponding to each opening portion 34 formed in the selection mask 33. A thickness of the InGaN layer 36 as the active layer is typically set to about 3 nm, and a thickness of the magnesium-doped GaN layer 37 is typically set to about 20 nm.

[0053]

A p-side electrode 15 is formed on the magnesium-doped GaN layer 37. The p-side electrode 15 typically has a stacked layer structure of Ni/Pt/Au or Ni(Pd)/Pt/Au formed by vapor-deposition. As one example of the stacked layer structure of the p-side electrode 15, an Ni layer having a thickness of about 1 nm, a Pt layer having a thickness of about 10 nm, and an Au layer having a thickness of about 100 nm are stacked in this order. The p-side electrode 15 is connected to the wiring layer 18

extending in the horizontal direction.

[0054]

An n-side electrode 23 formed on the side opposed to the p-side electrode 15 is taken as a common electrode. As shown in FIG. 4, the n-side electrode 23 having a stacked layer structure of Ti/Al/Pt/Au is formed in an opening portion 22 formed in the selection mask 33 by vapor-deposition. The n-side electrode 23 is connected to the under growth layer 32, and is electrically connected to the first conductive type cladding layer of the hexagonal pyramid shaped GaN layer 35 formed on the under growth layer 32 by selective growth. The n-side electrode 23 is connected to a wiring layer 21 extending, on the surface side of the n-side electrode 23, in the vertical direction, to receive supply of a current given to the light emitting diode.

[0055]

According to the display unit having the above-described configuration in this embodiment, at least the periphery of the device is surrounded by the planes grown from the tilt planes, and the conductive layers, that is, the GaN layer 35 as the cladding layer, the InGaN layer 36 as the active layer, and the magnesium-doped GaN layer 37 as the cladding layer are formed in self-alignment in

such a manner as to be terminated on the selection mask 33 as the insulating film used for selective grow. As a result, at the time of formation of electrodes, device isolation is not required or easily formed, so that it is possible to reduce the number of steps of fabricating the display unit. Also, according to the display unit in this embodiment, the emission of light of multi-colors can be realized by making use of the emission wavelength control functions of the dummy devices 12R, 13B and 14G. Further, the emission of light of multi-colors can be realized only by changing the arrangement patterns of the dummy devices of the selection masks while forming the light emitting devices having the same layer structure on the same sapphire substrate 10. Consequently, as compared with a display unit formed by combining light emitting devices formed by different fabrication processes, it is possible to significantly simplify the fabrication steps and to enhance the positional accuracy of the light emitting devices of the display unit.

[0056]

[Second Embodiment]

A display unit according to this embodiment will be described with reference to FIG. 5. The display unit in this embodiment is fabricated by forming semiconductor

light emitting devices for green, semiconductor light emitting devices for blue, and semiconductor light emitting devices for red on a sapphire substrate 41, 42 and 43, respectively, and sticking the sapphire substrates 41, 42 and 43 to each other. Referring to FIG. 5, green light emitting devices 51G are formed on the sapphire substrate 41, blue light emitting devices 51B are formed on the sapphire substrate 42, and red light emitting devices 51R are formed on the sapphire substrate 43.

[0057]

Only one light emitting diode is shown on each of the sapphire substrates 41, 42 and 43 in FIG. 5; however, in actual, a plurality of light emitting diodes are formed on each of the sapphire substrates 41, 42 and 43 in a matrix, and in the display unit formed by sticking the sapphire substrates 41, 42 and 43 to each other, pixels, each of which is composed of the three light emitting diodes for allowing emission of light of red, blue and green, are arrayed in the vertical and horizontal directions, that is, in a matrix. Each of the light emitting diodes 51R, 51B and 51G is fabricated by forming a first conductive type cladding layer, an active layer, and a second conductive type cladding layer on a

GaN based nitride semiconductor layer, and is formed into an approximately hexagonal pyramid shape. It is to be noted that light emitted from each of these devices is emerged in the direction "h" in FIG. 5.

[0058]

On the sapphire substrate 43, six dummy devices 63 are formed at points which are separated radially from the red light emitting diode 51R in six directions, and more specifically, formed at corners of a hexagonal shape centered at the red light emitting diode 51R. In other words, the red light emitting diode 51R is positioned at the center of the hexagonal shape having the six corners at which the dummy devices 63 are located. A GaN layer on the surface side of the red light emitting diode 51R is connected to an approximately rectangular p-side electrode 66. The p-side electrode 66 is integrated with or electrically connected to a thin, stripe shaped wiring layer 57 extending in the horizontal direction. Similarly, on the sapphire substrate 42, six dummy devices 62 are formed at points which are separated radially from the blue light emitting diode 51B in six directions, and more specifically, formed at corners of a flattened hexagonal shape (one pair of opposed sides longer than another pair of opposed sides) centered at the blue light emitting

diode 51B. In other words, the blue light emitting diode 51B is positioned at the center of the flattened hexagonal shape having the six corners at which the dummy devices 62 are located. Unlike the red light emitting diode 51R and the green light emitting diode 51G, the blue light emitting diode 51B is formed into a stripe shape. A GaN layer on the surface side of the blue light emitting diode 51B is connected to an approximately rectangular p-side electrode 65. The p-side electrode 65 is integrated with or electrically connected to a thin, stripe shaped wiring layer 56 extending in the horizontal direction. Similarly, on the sapphire substrate 41, six dummy devices 61 are formed at points which are separated radially from the green light emitting diode 51G in six directions, and more specifically, formed at corners of a hexagonal shape centered at the green light emitting diode 51G. In other words, the green light emitting diode 51G is positioned at the center of the hexagonal shape having the six corners at which the dummy devices 61 are located. A GaN layer on the surface side of the green light emitting diode 51G is connected to an approximately rectangular p-side electrode 64. The p-side electrode 64 is integrated with or electrically connected to a thin, stripe shaped wiring layer 55 extending in the horizontal

direction. It is to be noted that structures and functions of the dummy devices 63, 62 and 61 are substantially the same as those of the dummy devices 12R, 13B and 14G used for the display unit according to the first embodiment, and therefore, the overlapped description thereof is omitted.

[0059]

According to this embodiment, to obtain the display unit allowing emission of light of multi-colors, the sapphire substrates 41, 42 and 43, each of which allows emission of light of only a single color, are stacked to each other. For this purpose, each of the sapphire substrates 41, 42 and 43 is required to allow light to pass therethrough. For example, at least two, on the light emergence side in the direction "h", of the stacked substrates, that is, the substrates 42 and 43 are each required to allow light to pass therethrough. More specifically, the substrate 42 is required to allow light emitted from the light emitting diodes on the substrate 41 to pass therethrough, and the substrate 43 is required to allow both light emitted from the light emitting diodes on the substrate 41 and light emitted from the light emitting diodes on the substrate 42 to pass therethrough. Each of the sapphire substrates 41, 42 and



43 is generally excellent in light permeability and allows light to pass therethrough. To enhance the light permeability of each of the sapphire substrates 41, 42 and 43, a back surface side of the sapphire substrate may be thinned by grinding or polishing, or opening portions allowing light to pass therethrough may be formed in the sapphire substrate by etching. As the substrate in this embodiment, there may be used a substrate other than the sapphire substrate. For example, a red light emitting diode may be formed on a GaAs substrate, and each of blue and green light emitting diodes may be formed on the sapphire substrate. Alternatively, three substrates, or two substrates required to allow light to pass therethrough may be configured as plastic or glass substrates. In this case, light emitting diodes may be transferred on these plastic or glass substrates.

[0060]

In the case of stacking the substrates to each other, as described above, light is emerged from the light emitting diodes while passing through the substrates. Accordingly, the display unit fabricated by stacking the substrates to each other is required such that the light emitting diodes on one substrate are not overlapped to those on the other substrates, and a light

permeable region having a size of at least 1  $\mu\text{m}$  or more is formed in each region between two of a plurality of the light emitting diodes arrayed on each substrate for allowing light emitted from the light emitting diodes on the back surface side to pass through the light permeable regions. Since each of the sapphire substrates 41, 42 and 43 has the light permeability as described above, by broadening each gap as the light permeable region between two of the light emitting diodes on each substrate, light emitted from the light emitting diodes on the back surface side can be easily emerged outwardly via the gaps between devices as the light permeable regions.

[0061]

The wiring layers 52, 53 and 54 for supplying currents are formed on the sapphire substrates 41, 42 and 43 in such a manner as not to be overlapped to the light emitting diodes but to be located at the same position for easy wiring in the case of giving a common potential thereto. Since each of the wiring layers 52, 53 and 54 is formed of a thin metal film and thereby has a light shielding property, a total occupied area of the wiring layers 52, 53 and 54 is widened, the degree of freedom in design of the layout of the light emitting diodes is reduced. From this viewpoint, according to this

embodiment, since the wiring layers 52, 53 and 54 on the sapphire substrates 41, 42 and 43 are located at the same position, it is possible to increase the degree of freedom in design of the layout of the light emitting diodes.

[0062]

[Third Embodiment]

A display unit according to this embodiment will be described with reference to FIGS. 6 to 9. Like the display unit according to the first embodiment, the display unit according to this embodiment includes a display portion having a structure that pixels, each of which is composed of three semiconductor light emitting devices allowing emission of light of red, blue and green, are arrayed in the vertical and horizontal directions, that is, in a matrix.

[0063]

FIG. 6 is a plan view showing a configuration of a one pixel portion of the display unit according to this embodiment. Referring to FIG. 6, a red light emitting diode 71R, a blue light emitting diode 71B, and a green light emitting diode 71G are arrayed in such a manner as to be obliquely offset from each other in each of the vertical direction (V-direction in FIG. 6) and the

horizontal direction (H-direction in FIG. 6). Each of the light emitting diodes 71R, 71B and 71G is fabricated by forming a first conductive type cladding layer, an active layer, and a second conductive type cladding layer on a GaN based nitride semiconductor layer. These devices are formed on the same sapphire substrate 70 by the same processing steps. Each of the light emitting diodes 71R, 71B and 71G is formed into an approximately hexagonal pyramid shape. It is to be noted that light emitted from each of these devices is emerged in the direction from a front surface to a rear surface of the figure.

[0064]

A dummy device 72R is formed into the shape which extends along six sides of a hexagonal shape centered at the red light emitting diode 71R. In other words, the red light emitting diode 71R is positioned at the center of the hexagonal shape having the six sides along which the dummy device 72R extends. A magnesium-doped GaN layer of the red light emitting diode 71R is connected to an approximately rectangular p-side electrode 75. The p-side electrode 75 is integrated with or electrically connected to a thin, stripe shaped wiring layer 78 extending in the horizontal direction. Similarly, a dummy device 73B is formed into the shape which extends along six sides of a

flattened hexagonal shape (one pair of opposed sides longer than another pair of opposed sides) centered at the blue light emitting diode 71B. In other words, the blue light emitting diode 71B is positioned at the center of the flattened hexagonal shape having the six sides along which the dummy device 73B extends. Unlike the red light emitting diode 71R and the green light emitting diode 71G, the blue light emitting diode 71B is formed into a stripe shape. A magnesium-doped GaN layer of the blue light emitting diode 71B is connected to an approximately rectangular p-side electrode 76. The p-side electrode 76 is integrated with or electrically connected to a thin, stripe shaped wiring layer 79 extending in the horizontal direction. Similarly, a dummy device 74G is formed into the shape which extends along six sides of a hexagonal shape centered at the green light emitting diode 71G. In other words, the green light emitting diode 71G is positioned at the center of the hexagonal shape having the six sides along which the dummy device 74G extends. A magnesium-doped GaN layer of the green light emitting diode 71G is connected to an approximately rectangular p-side electrode 77. The p-side electrode 77 is integrated with or electrically connected to a thin, stripe shaped wiring layer 80 extending in the horizontal

direction.

[0065]

The dummy devices 72R, 73B and 74G will be described in detail below. The dummy device 72R (73B or 74G) is disposed around the light emitting diode 71R (71B or 71G) for setting a spacing factor of the light emitting diode 71R (71G or 71G). Since a wavelength of light emitted from the light emitting diode 71R (71B or 71G) is controlled by adjusting the spacing factor of the light emitting diode 71R (71B or 71G), the wavelength of light emitted from the light emitting diode 71R (71B or 71G) can be positively controlled by disposing the dummy device 72R (73B or 74G) around the light emitting diode 71R (71B or 71G). FIG. 7 shows a selective growth mask used for each of the red, blue and green light emitting diodes, and a pattern of each of the red, blue and green light emitting diodes and a dummy device formed by selective growth. In this figure, each selective growth mask is shown on the upper side, and the pattern of each of the light emitting diodes and the dummy devices is shown on the lower side.

[0066]

Referring to FIG. 7, a mask for red shown on the left side designated by character (R) has, at its center,

an opening portion 85R for selective growth of the red light emitting diode 71R and also has, at its periphery, an opening portion 86R for selective growth of the dummy device 72R. Concretely, the opening portion 86R is formed in the mask into the shape which extends along six sides of a hexagonal shape centered at the opening portion 85R. A size of the opening portion 85R may be set in a range of about 0.1  $\mu\text{m}$  to 10  $\mu\text{m}$ , and be formed into a polygonal shape such as an approximately hexagonal shape, a circular shape, or an elliptic shape. A distance between the opening portion 86R for forming the dummy device 72R and the opening portion 85R for forming the red light emitting diode 71R may be typically set to about 20  $\mu\text{m}$ . As a result, a size of the hexagonal shape formed by the opening portion 86R becomes about 40  $\mu\text{m}$ . By using such a mask for red, the hexagonal shaped red light emitting diode 71R and the dummy device 72R extending along the six sides of the hexagonal shape centered at the light emitting diode 71R are formed by selective growth from the opening portions 85R and 86R of the mask for red, respectively. The light emitting diode 71R positioned at the center is protected by the dummy device 72R.

[0067]

Referring to FIG. 7, a mask for blue shown at the

central portion designated by character (B) has, at its center, an approximately rectangular shaped opening portion 85B for selective growth of the blue light emitting diode 71B and also has, at its periphery, an opening portion 87B for selective growth of the dummy device 73B. Concretely, the opening portion 87B is formed in the mask into the shape which extends along six sides of a flattened hexagonal shape centered at the opening portion 85B. A size of the rectangular opening portion 85B may be typically set to a value being about two to ten times the size of the opening portion 85R. A distance between the opening portion 87B for forming the dummy device 73B and the opening portion 85B for forming the blue light emitting diode 71B may be set as follows: namely, a distance between the opening portion 87B and an end portion, closer to the opening portion 87B, of the rectangular shaped opening portion 85B may be set to about 20  $\mu\text{m}$ . As a result, a longitudinal size of the flattened hexagonal shape formed by the opening portion 87B extending along the six sides of the flattened hexagonal shape becomes a value obtained by adding the longitudinal size of the opening portion 85B to about 40  $\mu\text{m}$ . By using such a mask for blue, the hexagonal shaped blue light emitting diode 71B and the dummy device 73B



are formed by selective growth from the opening portions 85B and 87B of the mask for blue, respectively.

[0068]

Referring to FIG. 7, a mask for green shown on the right side designated by character (G) has, at its center, an opening portion 85G for selective growth of the green light emitting diode 71G and also has, at its periphery, an opening portion 88G for selective growth of the dummy device 74G. Concretely, the opening portion 88G is formed in the mask into the shape which extends along six sides of a hexagonal shape centered at the opening portion 85G. A size of the opening portion 85G may be set in a range of about 0.1  $\mu\text{m}$  to 10  $\mu\text{m}$ , and be formed into a polygonal shape such as an approximately hexagonal shape, a circular shape, or an elliptic shape. A distance between the opening portion 88G for forming the dummy device 74G and the opening portion 85G for forming the green light emitting diode 71G may be typically set to about 10  $\mu\text{m}$ . As a result, a size of the hexagonal shape formed by the opening portion 88G extending along the six sides of the hexagonal shape becomes about 20  $\mu\text{m}$ . By using such a mask for green, the hexagonal shaped green light emitting diode 71G and the dummy device 74G are formed by selective growth from the opening portions 85G and 88G of

the mask for green, respectively.

[0069]

Like the setting of the spacing factors of the light emitting diodes 11R, 11B and 11G by the dummy devices 12R, 13B and 14G, the spacing factors of the light emitting diodes 71R, 71B and 71G are set by the dummy devices 72R, 73B and 74G, whereby emission wavelengths of the light emitting devices 71R, 71B and 71G are made different from each other. According to this embodiment, the light emitting diodes 71R, 71B and 71G are formed on the same sapphire substrate 70 in such a manner that the light emitting diodes 71R, 71B and 71G have the same layer structure and the dummy devices 72R, 73B and 74G are disposed around the light emitting diodes 71R, 71B and 71G, respectively, so as to make the emission wavelengths of the light emitting diodes 71R, 71B and 71G different from each other. The present invention, however, is not limited thereto but may be configured such that one or two of light emitting diodes for red, blue and green have different layer structures, and dummy devices be provided around the remaining one or two light emitting diodes, respectively.

[0070]

A structure of each of the light emitting diodes

for red, blue and green and a structure of a wiring portion associated therewith will be described with reference to FIGS. 8 and 9. FIG. 8 is a sectional view taken on line VIII-VIII of FIG. 6, showing a sectional structure of the red light emitting diode 71R. The red light emitting diode 71R, the blue light emitting diode 71B and the green light emitting diode 71G have the same layer structure except for portions subjected to control of emission wavelengths by the dummy devices 72R, 73B and 74G (for example, impurity concentrations, crystal structures, and the like). Referring to FIG. 8, the red light emitting diode 71R is configured as a GaN based light emitting diode having a structure in which an under growth layer 92 typically composed of an AlN buffer layer and a silicon-doped GaN semiconductor layer is formed on the sapphire substrate 70 with the (C+)-plane of sapphire taken as a principal plane thereof, and a hexagonal pyramid shaped GaN layer 95 is formed thereon by selective growth. To be more specific, a selection mask 93 composed of a silicon oxide film is formed on the under growth layer 92, an opening portion 94 is formed in the selection mask 93, and the hexagonal pyramid shaped GaN layer 95 is selectively grown from the opening portion 94. The opening portion 94 is equivalent to the

opening portion 85R formed in the mask shown in FIG. 7. The hexagonal pyramid shaped GaN layer 95 is formed by selective growth from the opening portion 94 formed in the selection mask 93 by the MOCVD process or the like.

[0071]

In the case of growing the GaN layer 95 on the sapphire substrate 70 with the C-plane of sapphire taken as the principal plane thereof, the GaN layer 95 is formed into the hexagonal pyramid shape covered with the (1-101) planes called the S-planes. The conductive type of the GaN layer 95 is taken as an n-type by doping silicon into the GaN layer 95. The GaN layer 95 is grown from the opening portion 94 formed in the selection mask 93 in such a manner as to have the S-planes as the tilt planes, and one conductive layer will be formed in self-alignment on planes grown from the S-planes as the tilt planes of the GaN layer 95. It is to be noted that the GaN layer 95 is grown in self-alignment in such a manner as to be terminated on the selection mask 93 as the insulating film used for selective growth. The tilt plane portions, that is, the S-plane portions of the GaN layer 95 function as a cladding layer constituting part of a double-hetero structure. An InGaN layer 96 as an active layer is formed to cover the GaN layer 95, and a

magnesium-doped GaN layer 97 is formed on the InGaN layer 96. The magnesium-doped GaN layer 97 also functions as a cladding layer constituting part of the double-hetero structure. The magnesium-doped GaN layer 97 is grown in self-alignment, that is, extends along the tilt planes (S-planes) toward the selection mask 93 composed of the insulating film and is terminated on the selection mask 93. The terminated point of the magnesium-doped GaN layer 97 corresponds to the peripheral end portion of the light emitting device. Accordingly, in the case of fabricating the display unit, the GaN layer 95 as the cladding layer, the InGaN layer 96 as the active layer, and the magnesium-doped GaN layer 97 as the cladding layer are not required to be subjected to device isolation. In other words, each of the light emitting devices for forming the display unit can be arrayed in self-alignment at the position corresponding to each opening portion 94 formed in the selection mask 93. A thickness of the InGaN layer 96 as the active layer is typically set to about 3 nm, and a thickness of the magnesium-doped GaN layer 97 is typically set to about 20 nm.

[0072]

A p-side electrode 75 is formed on the magnesium-doped GaN layer 97. The p-side electrode 75 typically has

a stacked layer structure of Ni/Pt/Au or Ni(Pd)/Pt/Au formed by vapor-deposition. As one example of the stacked layer structure of the p-side electrode 75, an Ni layer having a thickness of about 1 nm, a Pt layer having a thickness of about 10 nm, and an Au layer having a thickness of about 100 nm are stacked in this order. The p-side electrode 75 is connected to the wiring layer 78 extending in the horizontal direction.

[0073]

An n-side electrode 83 formed on the side opposed to the p-side electrode 75 is taken as a common electrode. As shown in FIG. 9, the n-side electrode 83 having a stacked layer structure of Ti/Al/Pt/Au is formed in an opening portion 82 formed in the selection mask 93 by vapor-deposition. The n-side electrode 83 is connected to the under growth layer 92, and is electrically connected to the first conductive type cladding layer of the hexagonal pyramid shaped GaN layer 95 formed on the under growth layer 92 by selective growth. The n-side electrode 83 is connected to a wiring layer 81 extending, on the surface side of the n-side electrode 83, in the vertical direction, to receive supply of a current given to the light emitting diode.

[0074]

According to the display unit having the above-described configuration in this embodiment, at least the periphery of the device is surrounded by the planes grown from the tilt planes, and the conductive layers, that is, the GaN layer 95 as the cladding layer, the InGaN layer 96 as the active layer, and the magnesium-doped GaN layer 97 as the cladding layer are formed in self-alignment in such a manner as to be terminated on the selection mask 93 as the insulating film used for selective growth. As a result, at the time of formation of electrodes, device isolation is not required or easily formed, so that it is possible to reduce the number of steps of fabricating the display unit. Also, according to the display unit in this embodiment, the emission of light of multi-colors can be realized by making use of the emission wavelength control functions of the dummy devices 72R, 73B and 74G each extending in line. Further, the emission of light of multi-colors can be realized only by changing the arrangement patterns of the dummy devices of the selection masks while forming the light emitting devices having the same layer structure on the same sapphire substrate 70. Consequently, as compared with a display unit formed by combining light emitting devices formed by different fabrication processes, it is possible to

significantly simplify the fabrication steps and to enhance the positional accuracy of the light emitting devices of the display unit.

[0075]

[Fourth Embodiment]

A display unit according to this embodiment will be described with reference to FIGS. 10 to 15. The display unit in this embodiment is fabricated by forming semiconductor light emitting devices for red, semiconductor light emitting devices for blue, and semiconductor light emitting devices for green on sapphire substrate 100R, 100B and 100G, respectively, and sticking the sapphire substrates 100R, 100B and 100G to each other.

[0076]

FIG. 10 is a plan view showing, from above, a stack of the three sapphire substrates 100R, 100B and 100G. Each of a blue light emitting diode 101, a green light emitting diode 111, and a red light emitting diode 121 is fabricated by forming a first conductive type cladding layer, an active layer, and a second conductive type cladding layer on a GaN based nitride semiconductor layer, and has an approximately hexagonal pyramid shape formed by selective growth. A structure of each of the light



emitting diodes 101, 111, 121 is substantially the same as that of the light emitting diode 11R in the first embodiment, respectively. To obtain emission of light of blue, green and red, doped amounts of indium of active layers and the like of the light emitting diodes 101, 111, and 121 are controlled.

[0077]

FIGS. 11 to 13 are plan views showing the sapphire substrates 100B, 100G and 100R, respectively, wherein FIG. 11 shows the sapphire substrate 100B on which the blue light emitting devices 101 are formed, FIG. 12 shows the sapphire substrate 100G on which the green light emitting diodes 111 are formed, and FIG. 13 shows the sapphire substrate 100R on which the red light emitting diodes 121 are formed. Referring to FIG. 11, on the sapphire substrate 100B, the blue light emitting diodes 101 are arrayed in a matrix, and a plurality of horizontal wiring lines 102 extending in the horizontal direction and a plurality of vertical wiring lines 103 extending in the direction perpendicular to the horizontal wiring lines 102 are formed. The horizontal wiring lines 102 are connected to p-side electrodes of the blue light emitting diodes 101. N-side electrodes 104 of the blue light emitting diodes 101 are formed in opening portions formed

in a selection mask, and are connected to the vertical wiring lines 103. The n-side electrodes 104 are provided for the blue light emitting devices 101 in a one-to-one relationship; however, as described in the previous embodiments, they may be configured as one common electrode.

[0078]

Referring to FIG. 12, on the sapphire substrate 100G, the green light emitting diodes 111 are arrayed in a matrix, and a plurality of horizontal wiring lines 112 extending in the horizontal direction and a plurality of vertical wiring lines 113 extending in the direction perpendicular to the horizontal wiring lines 112 are formed. The arrangement pitch of the green light emitting diodes 111 is the same as that of the blue light emitting diodes 101; however, the arrangement of the green light emitting diodes 111 is offset from that of the blue light emitting diodes 101 by a distance equivalent to one device in the vertical direction in the figure. The horizontal wiring lines 112 are connected to p-side electrodes of the green light emitting diodes 111. N-side electrodes 114 of the green light emitting diodes 111 are formed in opening portions formed in a selection mask, and are connected to the vertical wiring lines 113. The

n-side electrodes 114 are provided for the green light emitting devices 111 in a one-to-one relationship; however, as described in the previous embodiments, they may be configured as one common electrode.

[0079]

Referring to FIG. 13, on the sapphire substrate 100R, the red light emitting diodes 121 are arrayed in a matrix, and a plurality of horizontal wiring lines 122 extending in the horizontal direction and a plurality of vertical wiring lines 123 extending in the direction perpendicular to the horizontal wiring lines 122 are formed. The arrangement pitch of the red light emitting diodes 121 is the same as that of the blue light emitting diodes 101; however, the arrangement of the red light emitting diodes 121 is offset from that of the green light emitting diodes 111 by a distance equivalent to one device in the vertical direction in the figure. The horizontal wiring lines 122 are connected to p-side electrodes of the red light emitting diodes 121. N-side electrodes 124 of the red light emitting diodes 121 are formed in opening portions formed in a selection mask, and are connected to the vertical wiring lines 123. The n-side electrodes 124 are provided for the red light emitting devices 121 in a one-to-one relationship;

however, as described in the previous embodiments, they may be configured as one common electrode.

[0080]

The vertical wiring lines 103 on the sapphire substrate 100B having the blue light emitting diodes 101, the vertical wiring lines 113 on the sapphire substrate 100G having the green light emitting diodes 111, and the vertical wiring lines 123 on the sapphire substrate 100R having the red light emitting diodes 121 are located at the same positions in the horizontal direction. Similarly, the n-side electrodes 104 on the sapphire substrate 100B, the n-side electrodes 114 on the sapphire substrate 100G, and the n-side electrodes 124 on the sapphire substrate 100R are located at the same positions in the horizontal and vertical directions. With this configuration, since the vertical wiring lines 103, 113 and 123 are overlapped to each other and the n-side electrodes 104, 114 and 124 are overlapped to each other, it is possible to facilitate wiring in the case of giving a common potential. Further, since the wiring lines are located at the same positions, it is possible to enhance the degree of freedom in design of layout of the light emitting diodes.

[0081]

A structure of each of the light emitting diodes for red, blue and green and a structure of a wiring portion associated therewith will be described with reference to FIGS. 14 and 15. FIG. 14 is a sectional view taken on line XIV-XIV of FIG. 11, showing a sectional structure of the blue light emitting diode 101. The blue light emitting diode 101 is configured as a GaN based light emitting diode. The blue light emitting diode 101 is configured such that an under growth layer 132 typically composed of an AlN buffer layer and a silicon-doped GaN semiconductor layer is formed on the sapphire substrate 100B with the (C+)-plane of sapphire taken as a principal plane thereof, and a hexagonal pyramid shaped GaN layer 135 is formed thereon by selective growth. To be more specific, a selection mask 133 composed of a silicon oxide film is formed on the under growth layer 132, an opening portion 134 is formed in the selection mask 133, and the hexagonal pyramid shaped GaN layer 135 is selectively grown from the opening portion 134. The opening portion 134 is equivalent to the opening portion 25R formed in the mask shown in FIG. 2. The hexagonal pyramid shaped GaN layer 135 is formed by selective growth from the opening portion 134 formed in the selection mask 133 by the MOCVD process or the like.

[0082]

In the case of growing the GaN layer 135 on the sapphire substrate 100B with the C-plane of sapphire taken as the principal plane thereof, the GaN layer 135 is formed into the hexagonal pyramid shape covered with the (1-101) planes called the S-planes. The conductive type of the GaN layer 135 is taken as an n-type by doping silicon into the GaN layer 135. The GaN layer 135 is grown from the opening portion 134 formed in the selection mask 133 in such a manner as to have the S-planes as the tilt planes, and one conductive layer will be formed in self-alignment on planes grown from the S-planes as the tilt planes of the GaN layer 135. It is to be noted that the GaN layer 135 is grown in self-alignment in such a manner as to be terminated on the selection mask 133 as the insulating film used for selective growth. The tilt plane portions, that is, the S-plane portions of the GaN layer 135 function as a cladding layer constituting part of a double-hetero structure. An InGaN layer 136 as an active layer is formed to cover the GaN layer 135, and a magnesium-doped GaN layer 137 is formed on the InGaN layer 136. The magnesium-doped GaN layer 137 also functions as a cladding layer constituting part of the double-hetero

structure. The magnesium-doped GaN layer 137 is grown in self-alignment, that is, extends along the tilt planes (S-planes) toward the selection mask 133 composed of the insulating film and is terminated on the selection mask 133. The terminated point of the magnesium-doped GaN layer 137 corresponds to the peripheral end portion of the light emitting device. Accordingly, in the case of fabricating the display unit, the GaN layer 135 as the cladding layer, the InGaN layer 136 as the active layer, and the magnesium-doped GaN layer 137 as the cladding layer are not required to be subjected to device isolation. In other words, each of the light emitting devices for forming the display unit can be arrayed in self-alignment at the position corresponding to each opening portion 134 formed in the selection mask 133. A thickness of the InGaN layer 136 as the active layer is typically set to about 3 nm, and a thickness of the magnesium-doped GaN layer 137 is typically set to about 20 nm.

[0083]

A p-side electrode 138 is formed on the magnesium-doped GaN layer 137. The p-side electrode 138 typically has a stacked layer structure of Ni/Pt/Au or Ni(Pd)/Pt/Au formed by vapor-deposition. As one example of the stacked

layer structure of the p-side electrode 138, an Ni layer having a thickness of about 1 nm, a Pt layer having a thickness of about 10 nm, and an Au layer having a thickness of about 100 nm are stacked in this order. The p-side electrode 138 is connected to the wiring layer 102 extending in the horizontal direction.

[0084]

An n-side electrode 104 formed on the side opposed to the p-side electrode 138 is taken as a common electrode. As shown in FIG. 15, the n-side electrode 104 having a stacked layer structure of Ti/Al/Pt/Au is formed in an opening portion 134 formed in the selection mask 133 by vapor-deposition. The n-side electrode 104 is connected to the under growth layer 132, and is electrically connected to the first conductive type cladding layer of the hexagonal pyramid shaped GaN layer 135 formed on the under growth layer 132 by selective growth. The n-side electrode 104 is connected to a wiring layer 103 extending, on the surface side of the n-side electrode 104, in the vertical direction, to receive supply of a current given to the light emitting diode.

[0085]

According to the display unit having the above-described configuration in this embodiment, at least the



periphery of the device is surrounded by the planes grown from the tilt planes, and the conductive layers, that is, the GaN layer 135 as the cladding layer, the InGaN layer 136 as the active layer, and the magnesium-doped GaN layer 137 as the cladding layer are formed in self-alignment in such a manner as to be terminated on the selection mask 133 as the insulating film used for selective growth. As a result, at the time of formation of electrodes, device isolation is not required or easily formed, so that it is possible to reduce the number of steps of fabricating the display unit. Also, according to this embodiment, it is possible to fabricate a display unit having light emitting devices arrayed at a high positional accuracy.

[0086]

In the above embodiment, the display unit is fabricated by a combination of light emitting diodes allowing emission of light of red, blue and green; however, the display unit can be fabricated by a combination of light emitting diodes allowing emission of light of other colors, for example, two colors or four or more colors. The light emitting devices of the present invention are not limited to light emitting diodes but may be semiconductor laser devices, or a combination of

semiconductor laser devices and light emitting diodes (LEDs). For example, dummy devices for controlling emission wavelengths may be formed for semiconductor laser devices. The purpose of provision of dummy devices is not limited to control of emission wavelengths. For example, dummy devices may be provided for protecting devices. The stacking order of substrates on which semiconductor light emitting diodes of respective colors are mounted can be freely changed.

[0087]

[Effects of the Invention]

As described above, according to the display unit of the present invention, since one conductive layer is formed in self-alignment on planes grown from the tilt planes, at the time of formation of electrodes, device isolation is eliminated or easily formed, with a result that it is possible to reduce the number of steps of fabricating the display unit. Also, since emission wavelengths of light emitting devices are controlled by dummy devices, the light emitting devices having a plurality of emission wavelengths can be formed on the same base body by the same fabrication process.

[Brief Description of the Drawings]

[FIG. 1]

FIG. 1 is a plan view showing a device layout of one pixel portion of a display unit according to a first embodiment of the present invention.

[FIG. 2]

FIG. 2 is a plan view showing a pattern of a selection mask for each light emitting diode of the display unit according to the first embodiment (upper side) and a plane pattern of the light emitting diode (lower side).

[FIG. 3]

FIG. 3 is a sectional view taken on line III-III of FIG. 1, showing a red light emitting diode of the display unit according to the first embodiment.

[FIG. 4]

FIG. 4 is a sectional view taken on line IV-IV of FIG. 1, showing the red light emitting diode of the display unit according to the first embodiment.

[FIG. 5]

FIG. 5 is an exploded perspective view typically showing one pixel portion of a display unit according to a second embodiment of the present invention.

[FIG. 6]

FIG. 6 is a plan view showing one pixel portion of

a display unit according to a third embodiment of the present invention.

[FIG. 7]

FIG. 7 is a plan view showing a pattern of a selection mask for each light emitting diode of the display unit according to the third embodiment (upper side) and a plane pattern of the light emitting diode (lower side).

[FIG. 8]

FIG. 8 is a sectional view taken on line VIII-VIII of FIG. 6, showing a red light emitting diode of the display unit according to the third embodiment.

[FIG. 9]

FIG. 9 is a sectional view taken on line IX-IX of FIG. 6, showing the red light emitting diode of the display unit according to the third embodiment.

[FIG. 10]

FIG. 10 is a plan view showing a device layout of one pixel portion of a display unit according to a fourth embodiment of the present invention.

[FIG. 11]

FIG. 11 is a plan view showing a layout of blue light emitting diodes of the display unit according to the fourth embodiment.

[FIG. 12]

FIG. 12 is a plan view showing a layout of green light emitting diodes of the display unit according to the fourth embodiment.

[FIG. 13]

FIG. 13 is a plan view showing a layout of red light emitting diodes of the display unit according to the fourth embodiment.

[FIG. 14]

FIG. 14 is a sectional view taken on line XIV-XIV of FIG. 11, showing the blue light emitting diode of the display unit according to the fourth embodiment; and

[FIG. 15]

FIG. 15 is a sectional view taken on line XV-XV of FIG. 11, showing the blue light emitting diode of the display unit according to the fourth embodiment.

[Description of Reference Numerals]

11R, 51R, 71R, 121: red light emitting diode

11B, 51B, 71B, 101: blue light emitting diode

11G, 51G, 71G, 111: green light emitting diode

12R, 13B, 14G, 61, 62, 63, 72R, 73B, 74G: dummy device

10, 41, 42, 43, 70, 100B, 100G, 100R: sapphire substrate

[Name of Document] Abstract of the Disclosure

[Abstract]

[Object] To provide a display unit has a structure suitable for multi-colors without increasing the number of production steps so much.

[Solving Means] A display unit includes a plurality of semiconductor light emitting devices 11R, 11B, 11G arrayed on a base body 10, characterized in that each of the semiconductor light emitting devices 11R, 11B, 11G is formed together with dummy devices 12R, 13B, 14G for setting an emission wavelength of the semiconductor light emitting device, and that the semiconductor light emitting device 11R, 11B, 11G is formed by selective growth, and one conductive layer is formed in self-alignment on planes grown from tilt planes formed by selective growth.

[Selected Drawing] FIG. 1

[FIG. 1]

11R: RED LED

11B: BLUE LED

11G: GREEN LED

[FIG. 3]

15: p-SIDE ELECTRODE

39: SiO<sub>2</sub> FILM

33: SELECTION MASK

10: SAPPHIRE SUBSTRATE

[FIG. 4]

23: n-SIDE ELECTRODE

[FIG. 5]

51R: RED LED

51B: BLUE LED

51G: GREEN LED

[FIG. 8]

75: p-SIDE ELECTRODE

99: SiO<sub>2</sub> FILM

93: SELECTION MASK

70: SAPPHIRE SUBSTRATE

Fig 1

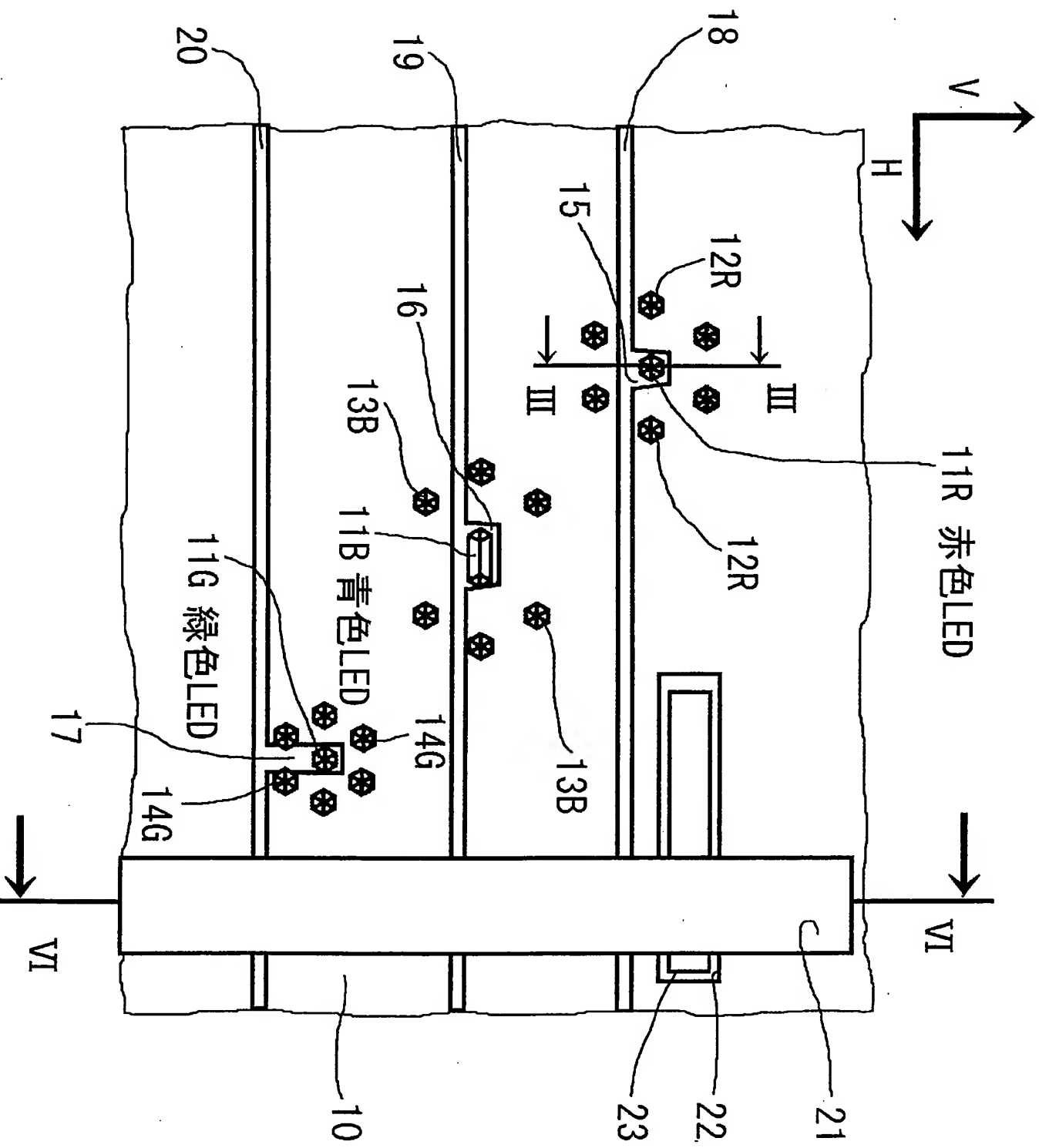




Fig 2

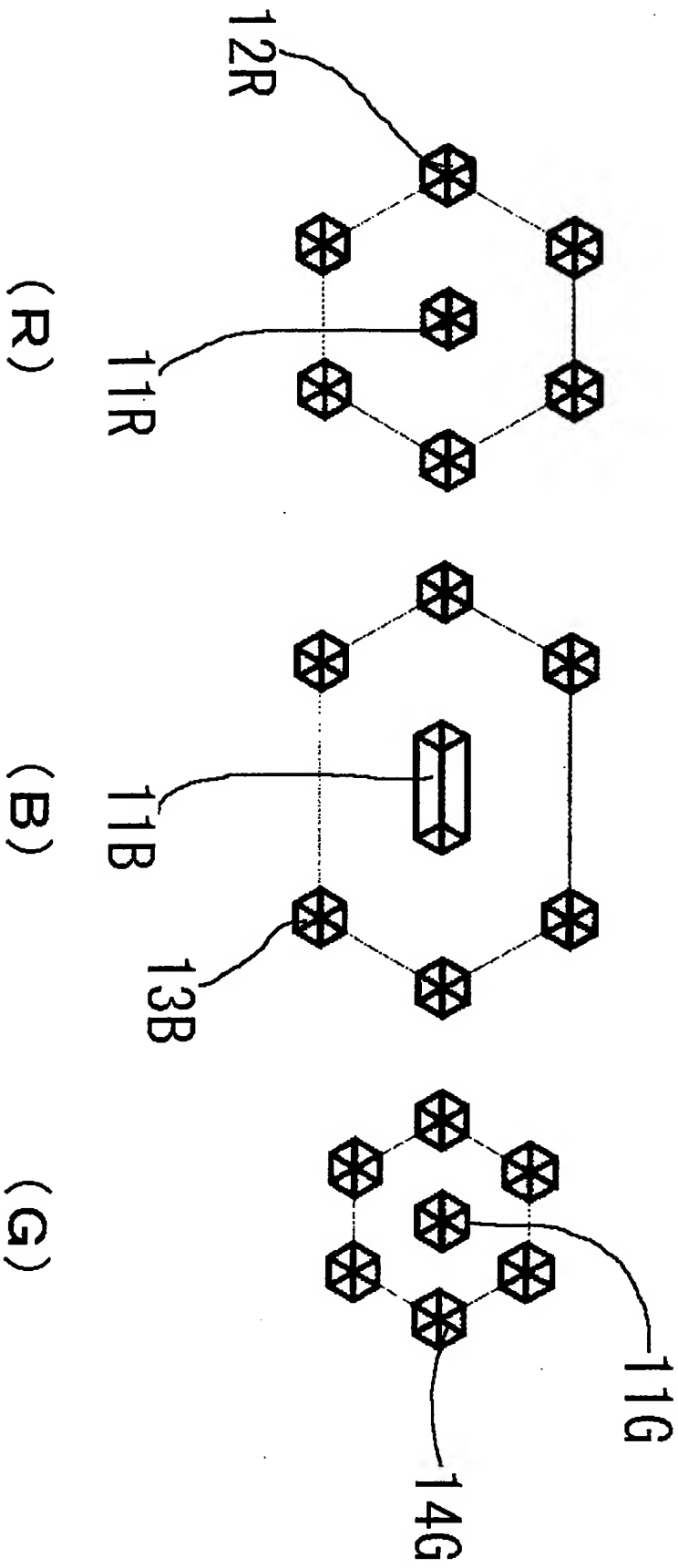
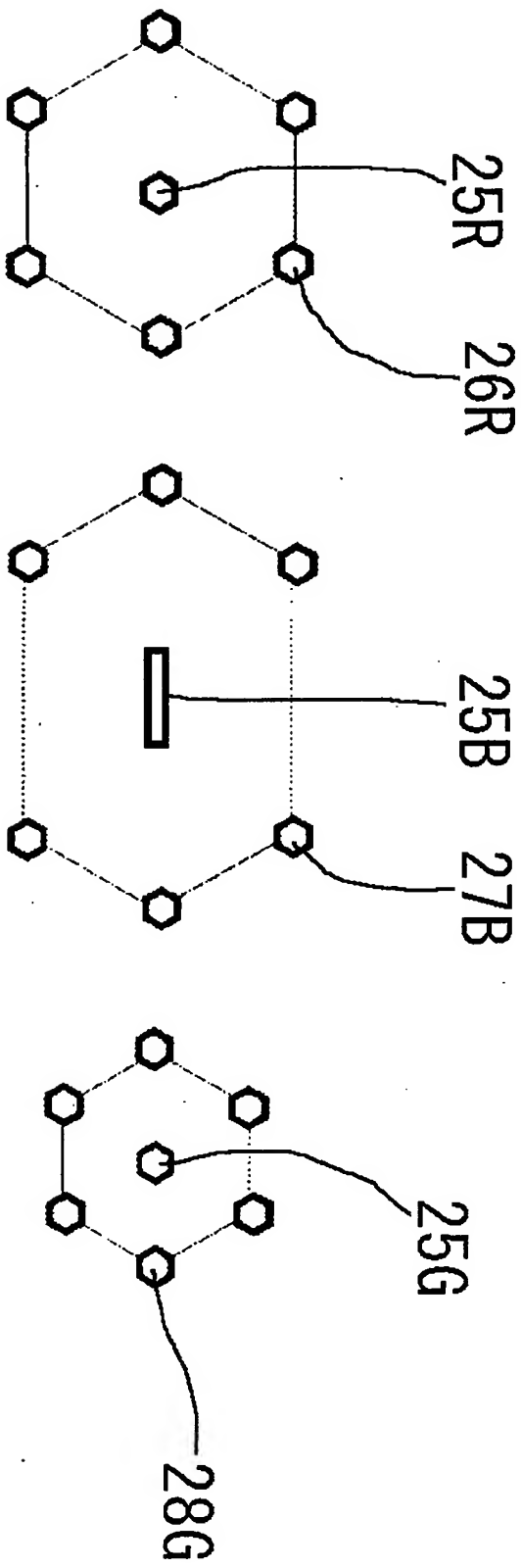


Fig 3

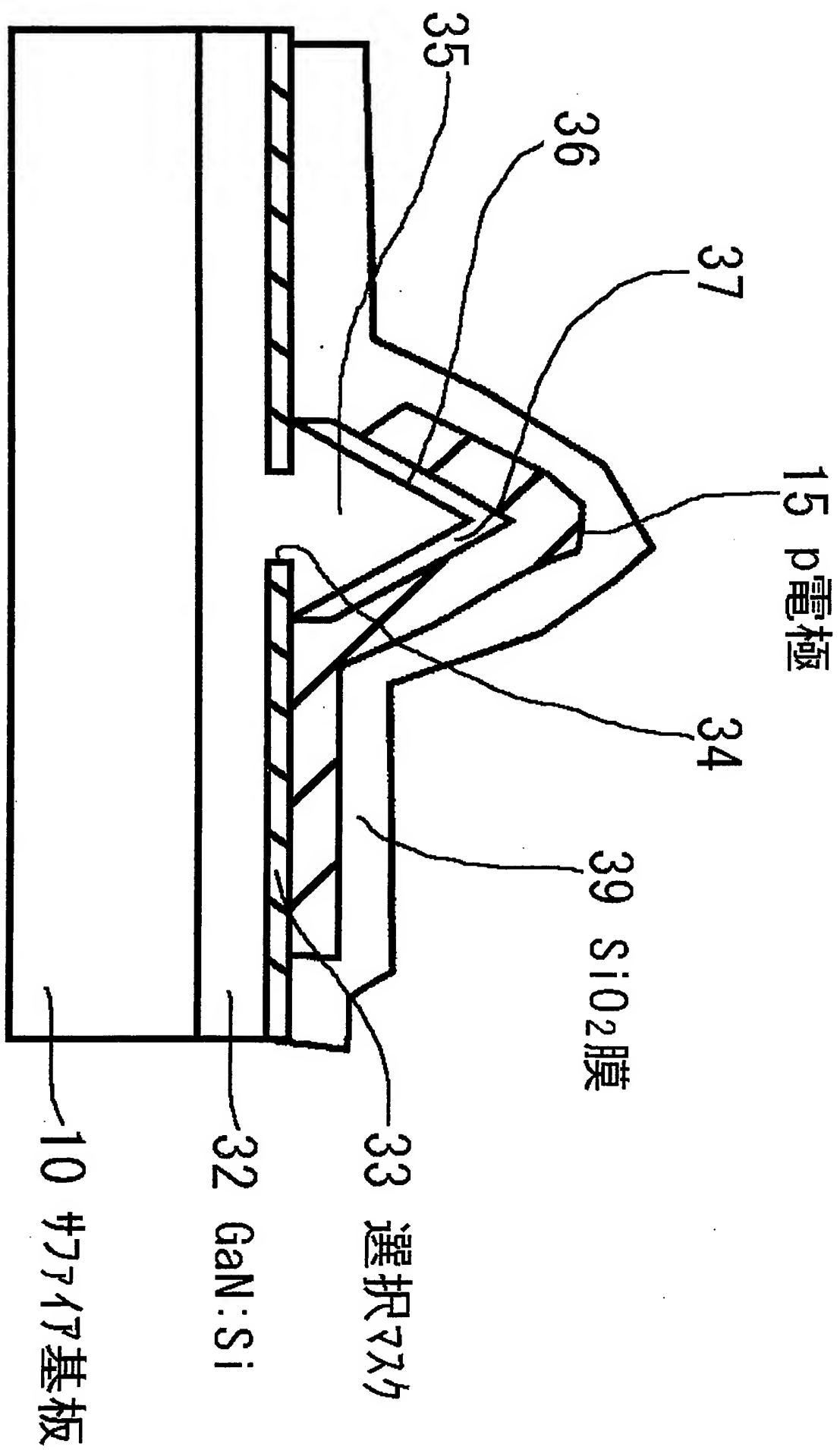


Fig 4

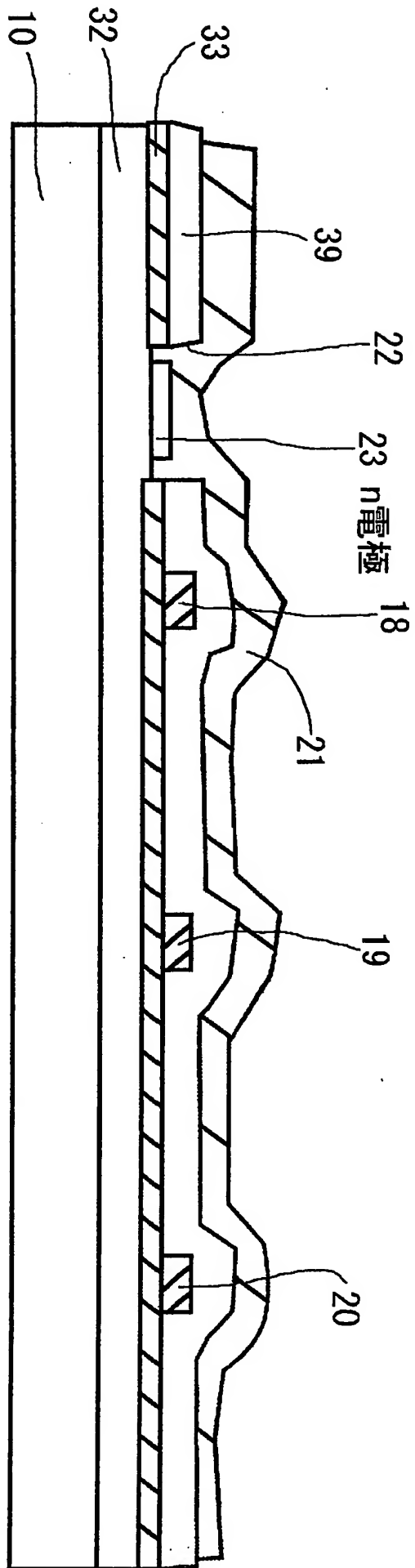


Fig 5

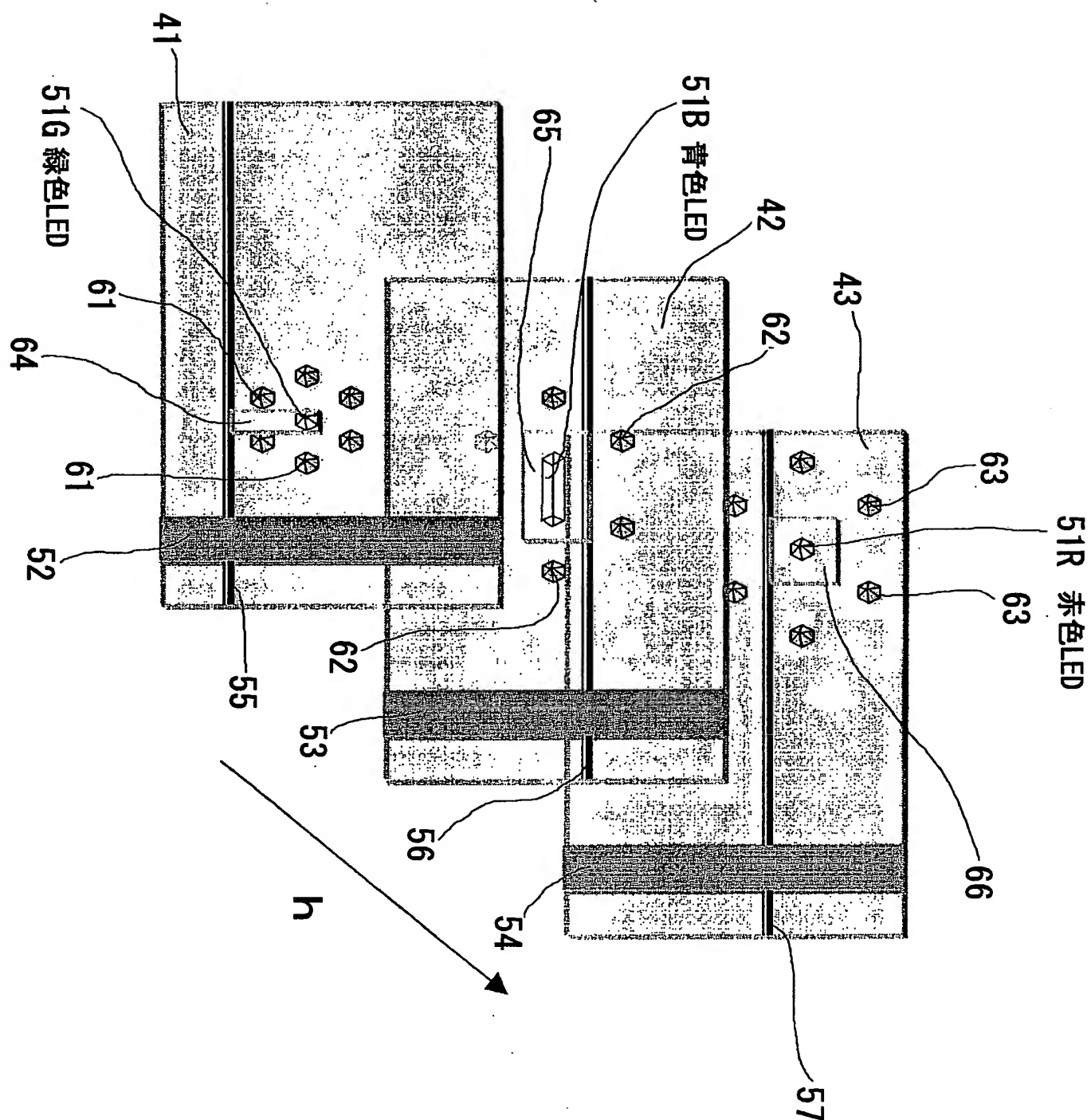


Fig 6

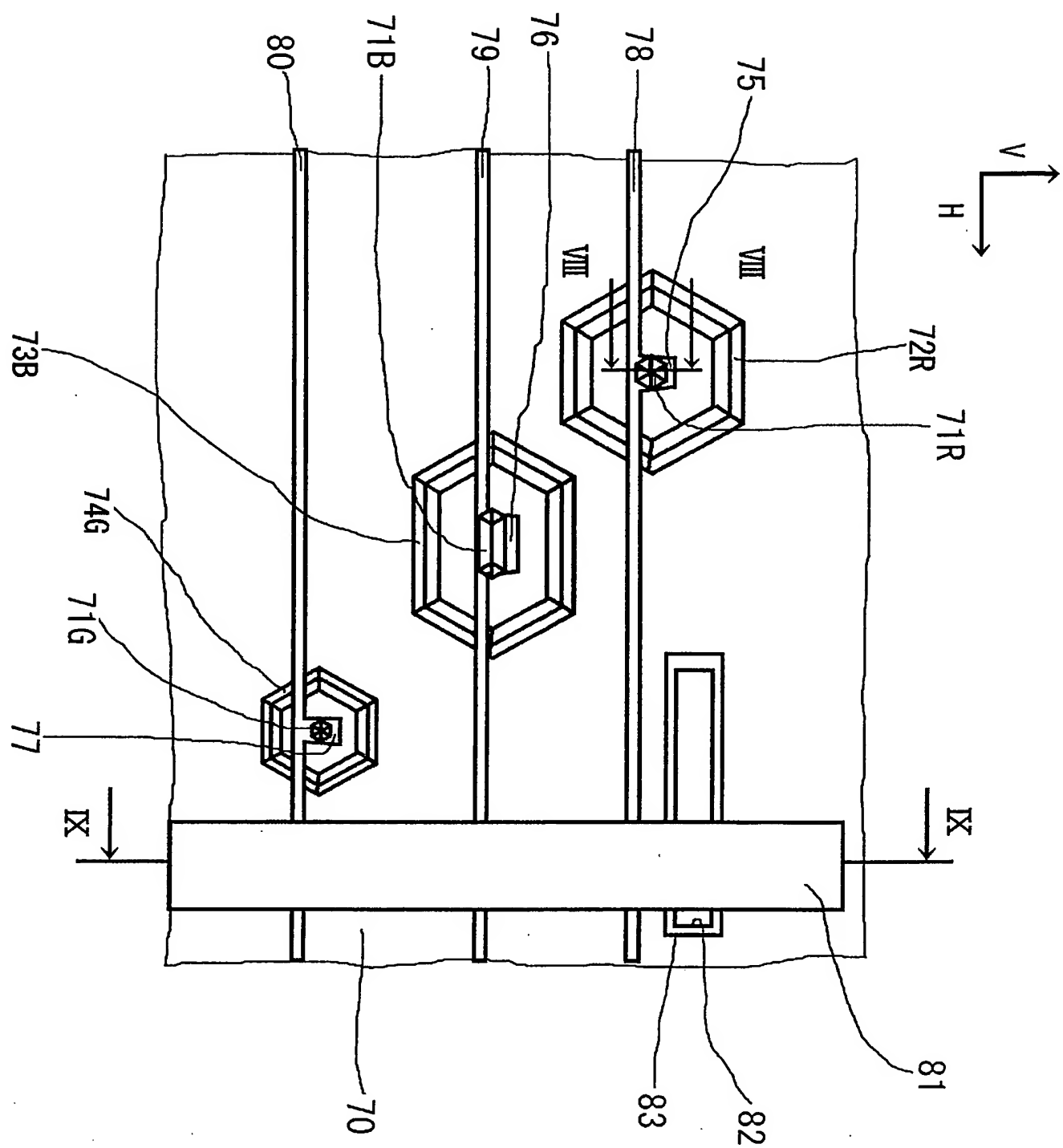


Fig 7

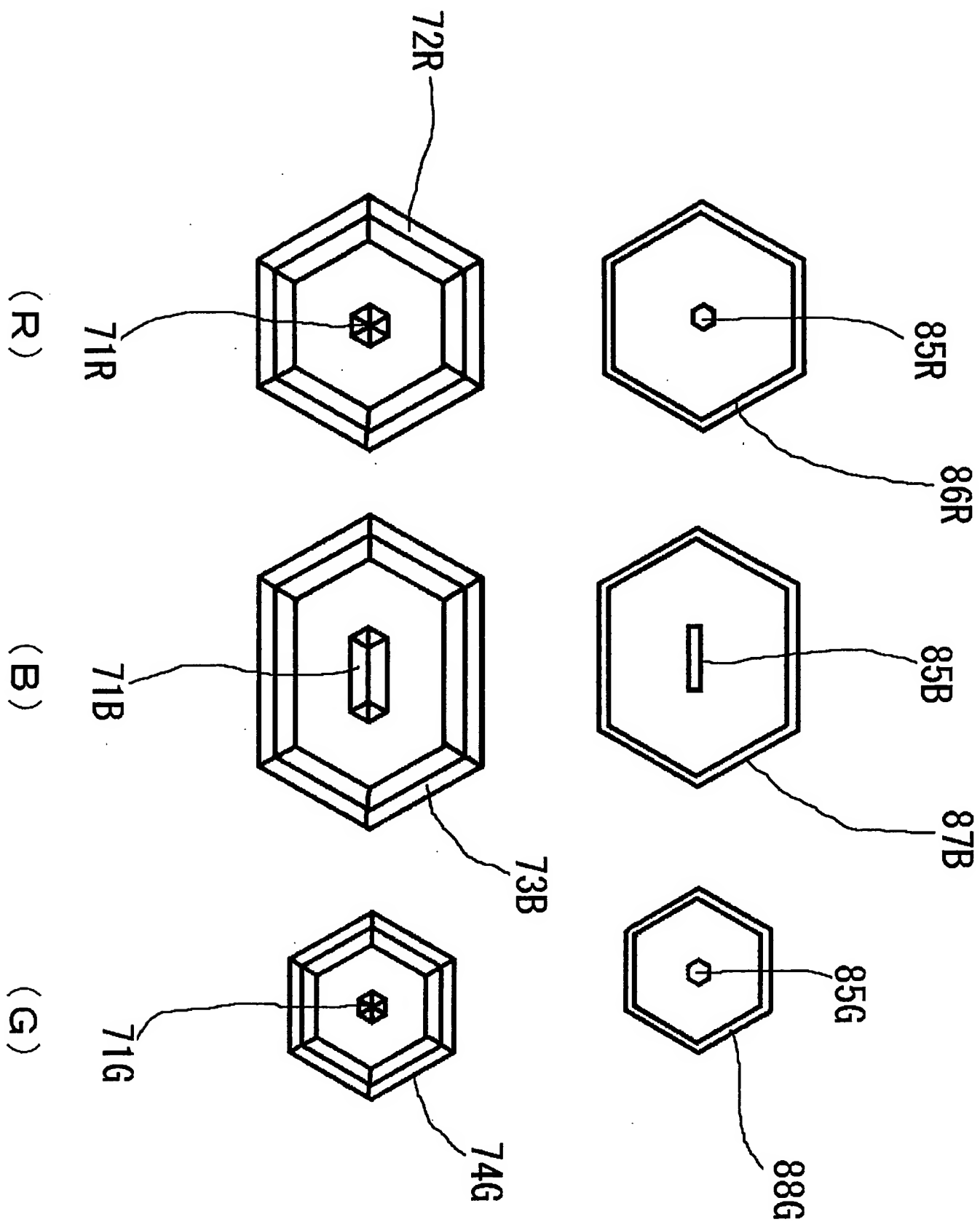


Fig 8

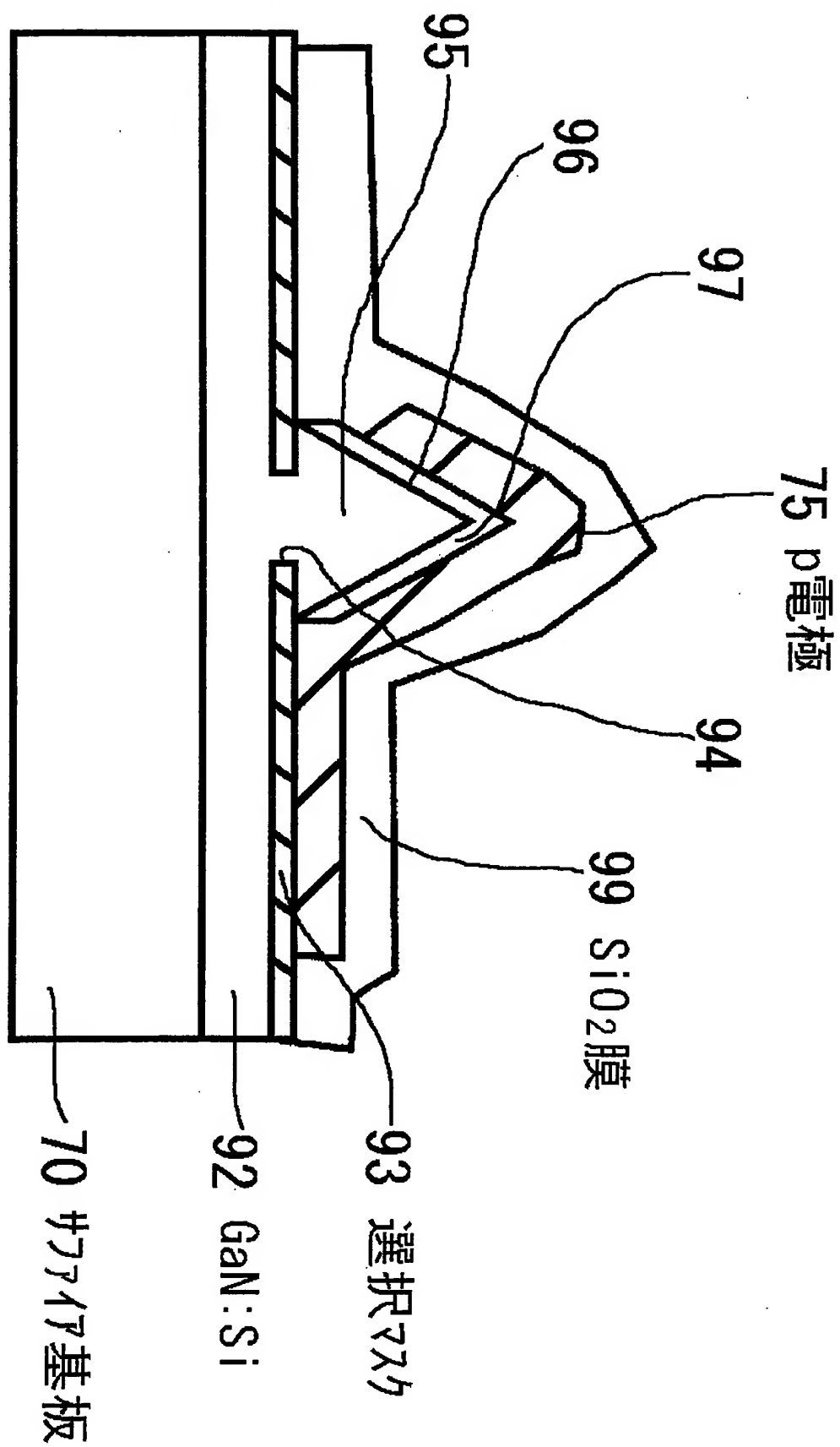


Fig 9

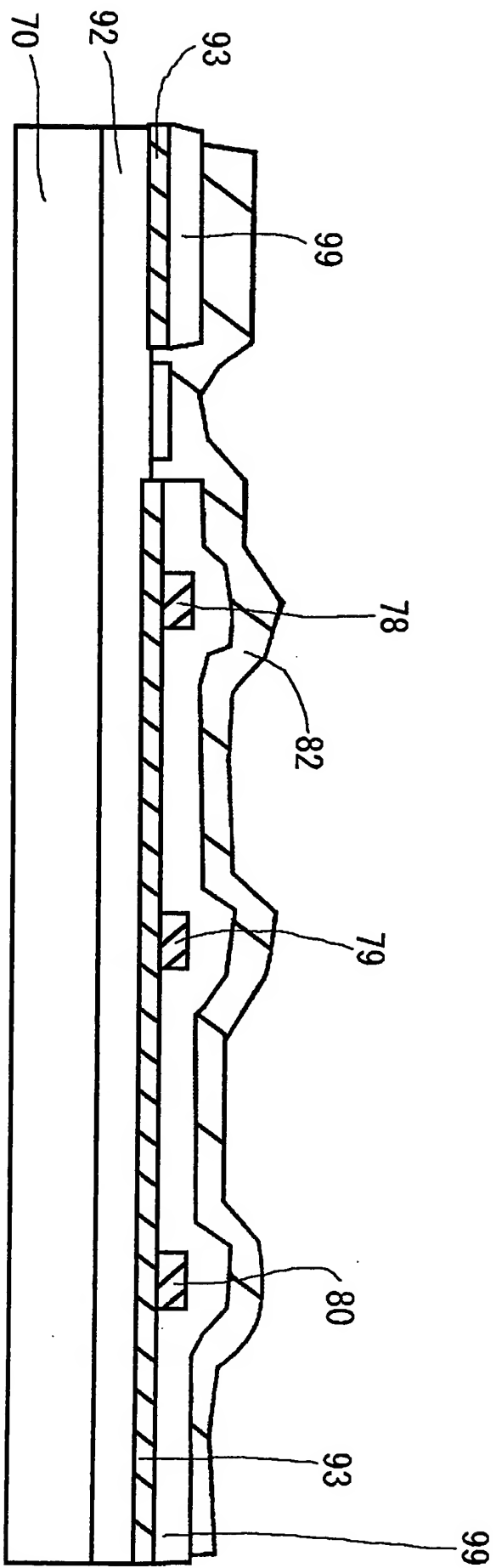




Fig 10

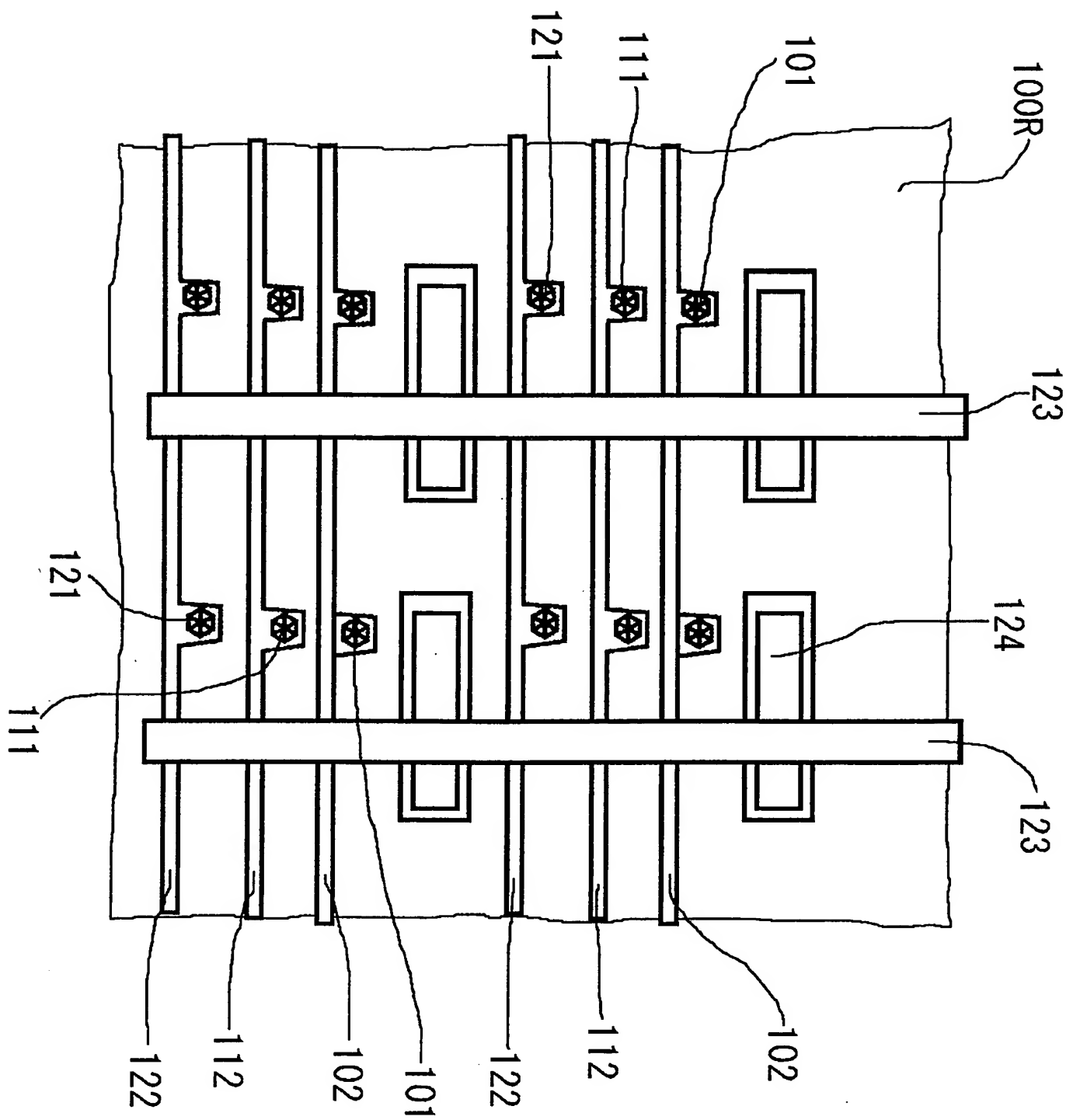


Fig 11

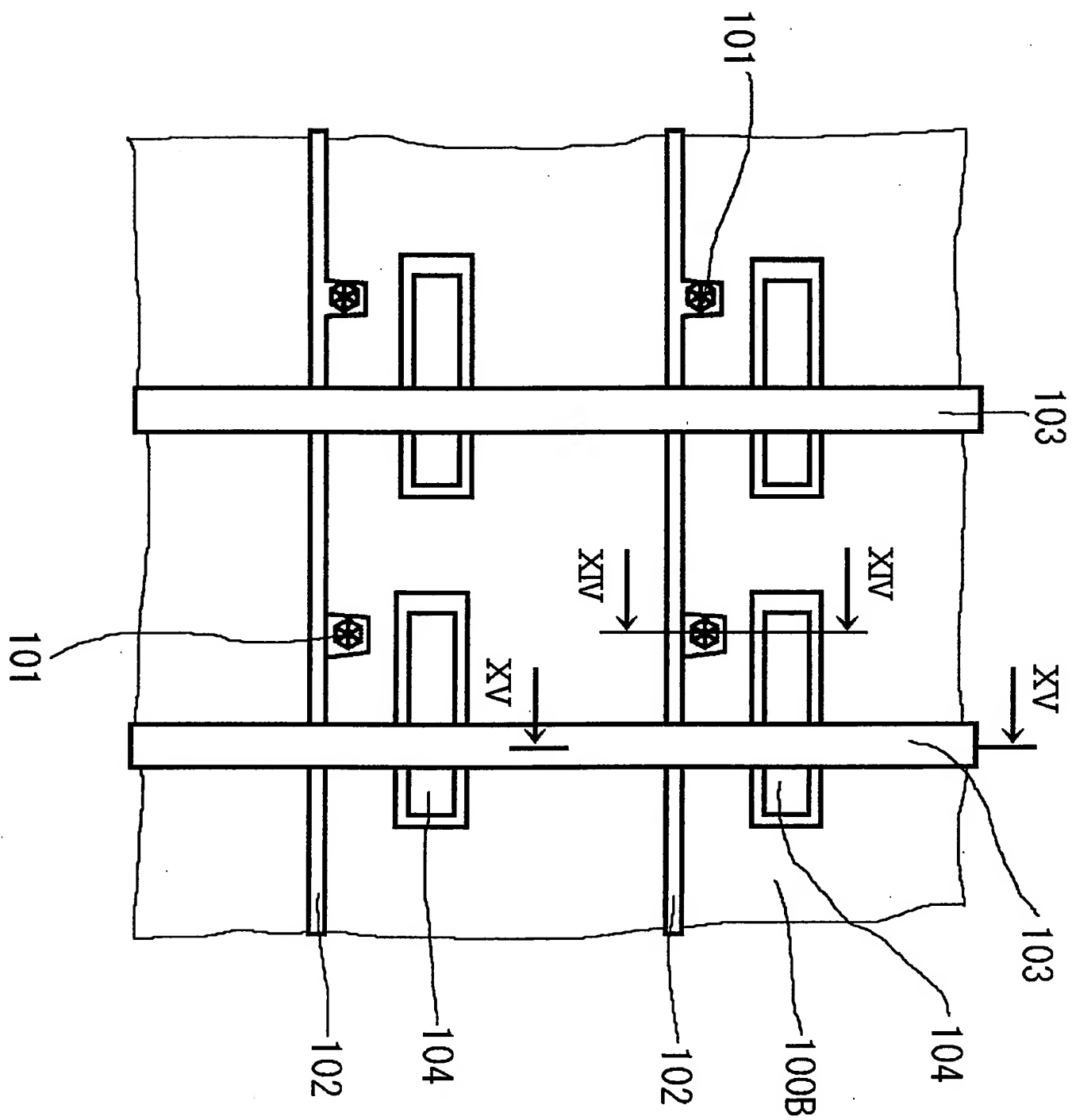


Fig 12

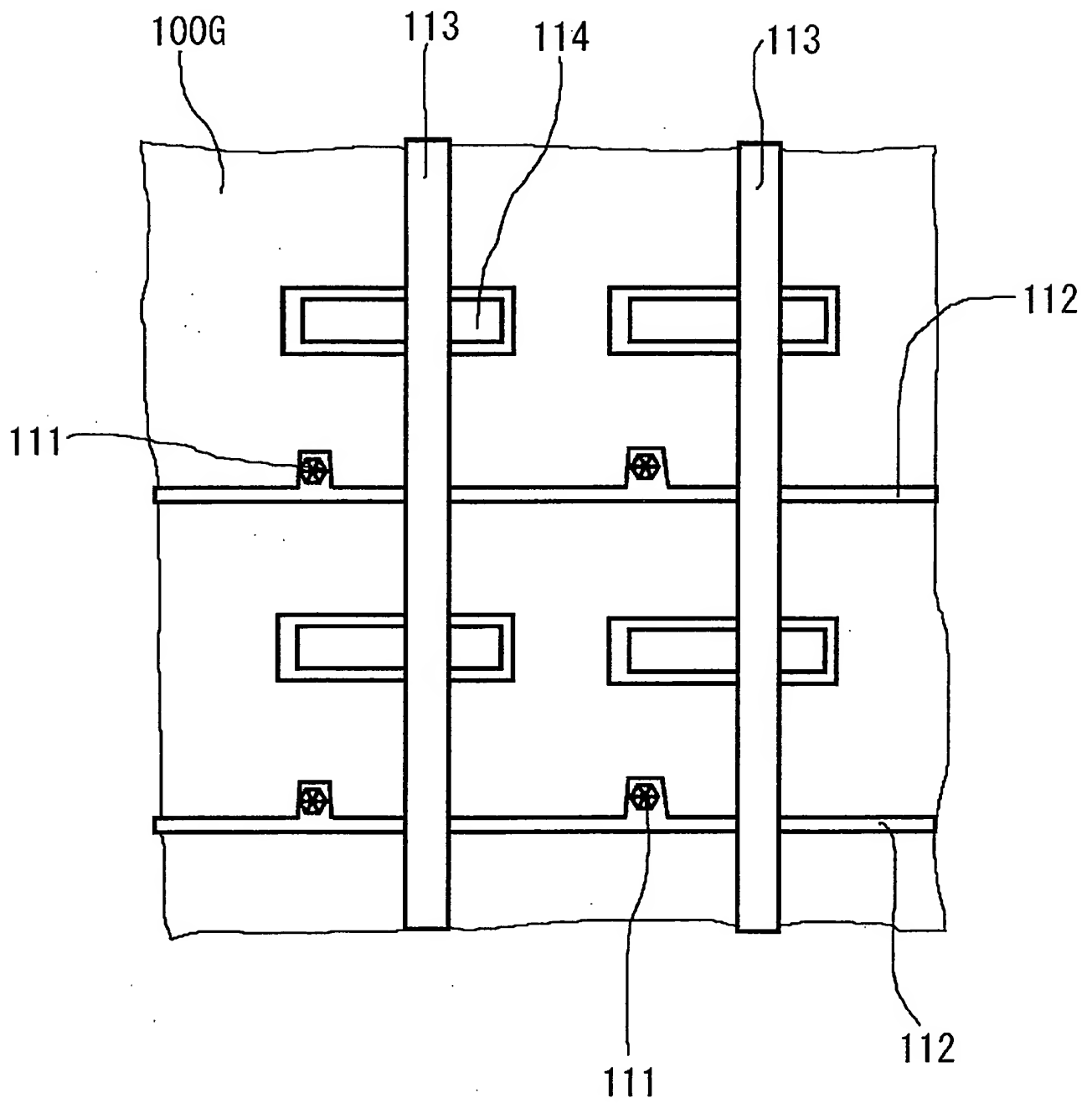


Fig 13

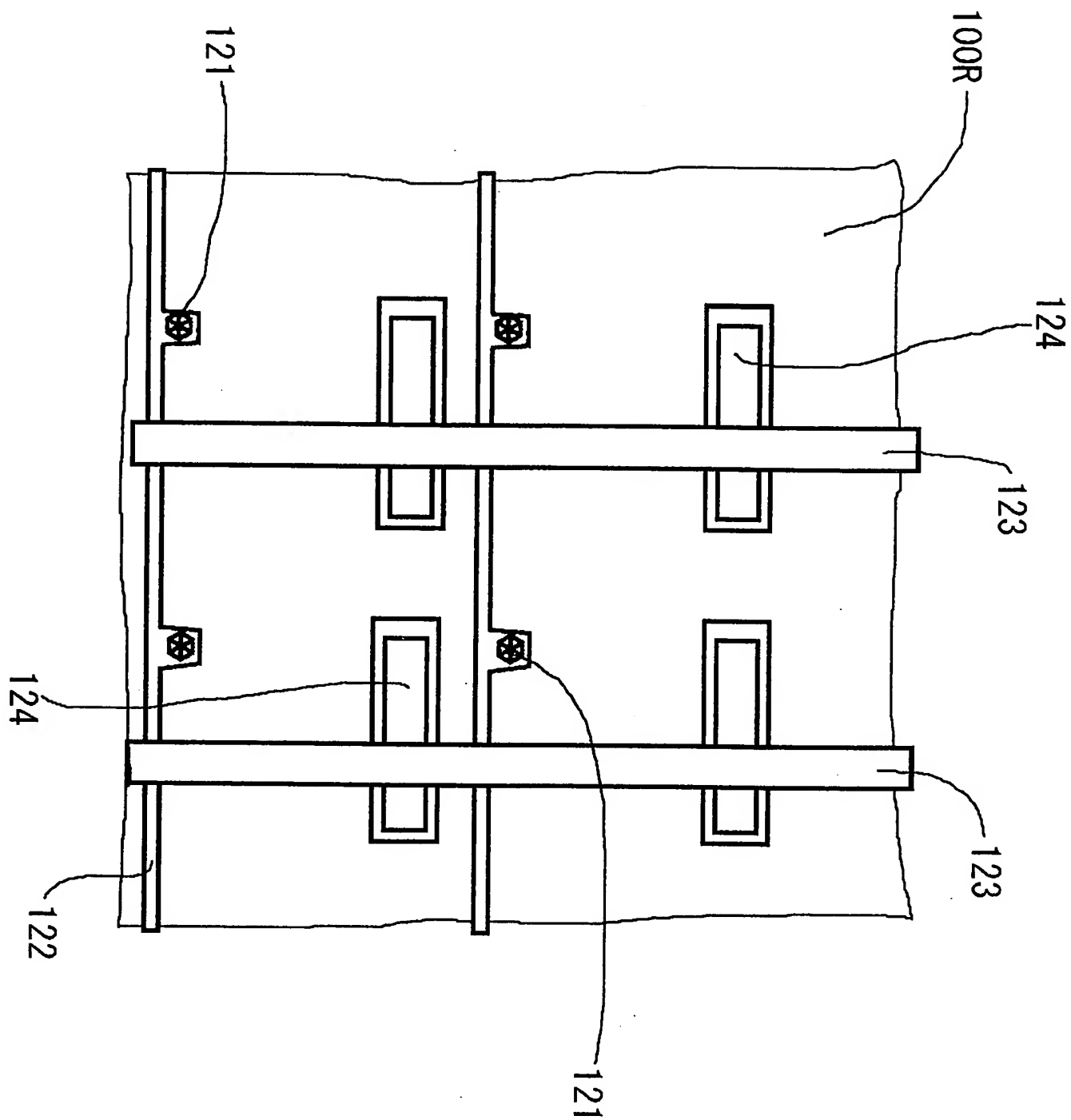


Fig 14

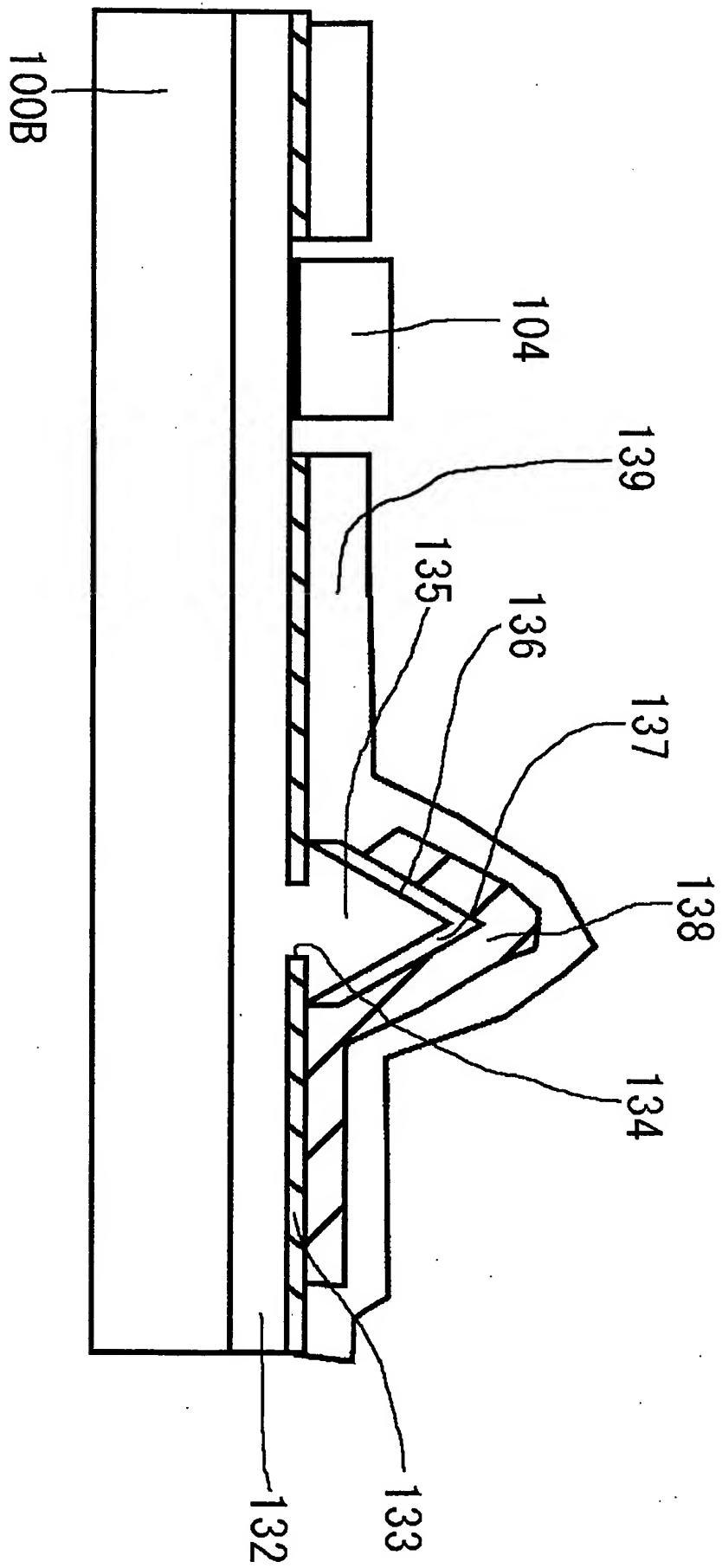


Fig 15

